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THE POTENTIAL IMPACT OF AIRCRAFT EMISSIONS
UPON AIR QUALITY

by
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INTRODUCTION

Background

An awareness of air pollutant emissions from aircraft developed in the late 1950's with the introduction into service of turbine-engine aircraft. Visible exhaust plumes from turbojet engines and increased levels of exhaust odors at airports gave rise to complaints against these perceptible manifestations of aircraft emissions. These complaints, in turn, stimulated investigations by public health agencies into the nature and extent of aircraft emissions, and these investigations have continued unabated in the intervening years.

In 1968, Northern Research and Engineering Corporation conducted a survey of information on aircraft emissions and their control. This investigation was sponsored by the National Air Pollution Control Administration and resulted in a comprehensive report on the nature and control of aircraft emissions (Ref 1). This investigation was directed primarily at an assessment of the extent or magnitude of aircraft emissions, and identification of approaches to reducing emission rates. The investigation also included an approximate analysis of the dispersion of aircraft emissions and the resulting exposures outside airport boundaries. The report represents the state of our understanding of the subject in 1968, and identifies the principal sources of information on aircraft emissions which existed at the time.

Since 1968, several organizations have been active in further investigations of various aspects of aircraft emission control. The NREC staff, in 1969, conducted a detailed analysis of the implementation times and costs of controlling visible smoke emission by "retrofitting" low-smoke combustors in existing turbine engines (Ref 2). In 1970, Scott Research Laboratories completed an investigation of emissions from aircraft piston engines which resulted in the first significant source of information on this subject (Ref 3). In 1971, a series of papers on aircraft emissions were presented at a conference on "Aircraft and the Environment" sponsored by SAE and DOT (Ref 4), and the results of this conference were summarized in a paper by Paullin (Ref 5). These investigations (Refs 2 through 5), in our opinion, have produced the most

significant contributions to the over-all subject of aircraft emissions since 1968. There have, of course, been many advances in more specific areas of emission impact and control. Many of these works will be cited later in this report.

The investigation described in this report was initiated in response to requirements in Section 231 of the Clean Air Amendments of 1970. Specifically, this section calls for an investigation of emissions of air pollutants from aircraft to determine:

1. The extent to which such emissions affect air quality in air quality control regions throughout the United States.
2. The technical feasibility of controlling such emissions.

Based upon the information generated by such a study, Section 231 of the Act also requires the Environmental Protection Agency to issue proposed emission standards applicable to any class or classes of aircraft or aircraft engines which cause or contribute to air pollution which endangers the public health or welfare, and to establish an implementation schedule commensurate with available technology and reasonable cost of compliance.

In order to carry out the above requirements, the responsibilities within the Environmental Protection Agency were divided. The National Environmental Research Center, Research Triangle Park, Office of Research and Monitoring, had primary responsibility to assess the impact of aircraft emissions on air quality. The Mobile Source Pollution Control Program, Office of Air Programs, independently initiated a study to assess the technical feasibility of controlling aircraft pollutant emissions and the costs associated therewith.

This report has been prepared for the National Environmental Research Center, Research Triangle Park, and is concerned with the impact of aircraft emissions. A parallel investigation of aircraft emission control technology has been conducted by NREC for the Mobile Source Pollution Control Program. The results of the control technology investigation are contained in a companion report (Ref 6).

Objectives

The over-all objective of the two investigations was to provide information towards establishing the impact of aircraft emissions and the

feasibility of their control, and to provide information necessary for establishing standards on emissions from aircraft activities. The information required to establish such standards falls into the following categories:

1. Methods for controlling emissions from aircraft activities.
2. Instrumentation requirements for measuring aircraft emissions.
3. Rates of emission of various pollutants at airports from aircraft activities.
4. Impact of emissions from aircraft activities in airport vicinities.

Information on emission control methods is necessary to determine the levels to which it is feasible to reduce aircraft emissions. The results of an earlier NREC study (Ref 1) indicated that practical control approaches include modifications of aircraft engines, fuels, and ground operational procedures. Thus, an assessment of control methods must be concerned with each of these categories of approaches. In assessing the feasibility of a control method, three factors must be explored: the cost of utilizing the method, the effects of the method on the functioning or capacity of the aircraft system, and the effectiveness of the method in reducing emissions.

Information on emission measurement instrumentation is necessary to assure that aircraft emissions can be measured with the accuracy and sensitivity necessary to enforce the desired standards. Measurements will be required for engines operated under test conditions in the laboratory and engines being operated while installed in all types of aircraft. It is not necessary, for the purpose of enforcing emission standards, that measurements be taken on engines in moving aircraft, either on the ground or in flight.

Total rates of emission of various pollutants from the different operating modes of aircraft activity are useful as indicators of the relative importance of these modes in the over-all airport air quality. Total emission rates also provide a gross measure of the relative importance of the contributions to community air pollution from aircraft, other emission sources at the airport, and sources outside the airport.

Information on the impact of aircraft emissions is necessary to determine the levels to which emission rates must be reduced so as not to exceed national primary and secondary ambient air quality standards. In practice, this information will relate the rates of emission at the airport to pollutant levels within the airport and in the airport vicinity.

The specific objectives of this investigation of the impact of aircraft emissions were:

1. To select representative airports for which detailed studies would be made of emissions and impact;
2. To determine aircraft emission factors and activity levels for the selected airports;
3. To determine total emission rates from aircraft activity and the impact of these emissions at the selected airports;
4. To develop future projections of emission rates and their impact at the selected airports;
5. To determine emission rates and impact of unburned fuel resulting from fuel venting and other practices directly associated with aircraft operating cycles.

Methodology

In order to accomplish the objectives of the investigation of the impact of aircraft emissions, five inter-related tasks corresponding to the objectives were executed. Those tasks were entitled:

1. Selection of Airports.
2. Analysis of Aircraft Emission Factors and Activity Levels.
3. Air Quality Analysis.
4. Future Projections of Emissions and Impact.
5. Analysis of Unburned Fuel Emissions.

The selection of airports was accomplished from lists of candidate airports based on a set of selection criteria. The selected airports were originally to include:

1. At least one military air base.
2. At least one joint civil-military installation.
3. One airport with a relatively high usage by piston driven aircraft.

4. A selection of large metropolitan airports.

The first two categories of airports were subsequently eliminated from consideration. The first category was eliminated from the present study due to difficulty in obtaining activity and operations data. The second category was dropped due to the scarcity of such installations. The primary selection criteria among candidate airports was aircraft activity level. Other criteria were proximity of airport boundaries and mean wind speed.

The second task was performed in two separate subtasks. The first subtask was concerned with the development of aircraft emission factors*. This was accomplished by first dividing aircraft into twelve classes and the operational cycle of the aircraft into ten modes. A total of eight different pollutants were considered: carbon monoxide, nitrogen oxides, sulfur dioxide, dry particulates, lead, total hydrocarbons, reactive hydrocarbons, and aldehydes. Typical engine emission data were then obtained for all operating conditions of engines used in each aircraft class. Aircraft operational data were then used to obtain emission factors for each mode of aircraft operation. Emission data were also obtained for other emission sources within the airport and the surroundings. The second subtask was concerned with the determination of activity levels and other pertinent information for the selected airports. Activity levels were classified by aircraft class, time of day, day of week, and month of year. Projections of aircraft activity through 1980 were also obtained. Airport information on the location and use of terminals, hangars, taxiways, runways, roadways, fuel storage areas, and heating plant was also obtained.

The third task, air quality analysis, was divided into three subtasks. The first subtask was concerned with the development of a computer program to perform the air quality analysis. The computer program was based on a detailed model of airport emissions and atmospheric dispersion. The computer program was debugged and its predictions compared to available data. A parametric analysis was then performed to determine the

* Aircraft emission factors are defined as constants which are characteristic of pollutant emission for an operating mode of a class of aircraft.

sensitivity of pollutant concentrations to various model parameters.

The second subtask was concerned with an air quality analysis of the selected airports. Total emissions were obtained for each airport by aircraft classes, aircraft operating modes, ground and flight operations, automobile activity, heating plant activity, and fuel storage usage. Variations of emissions with time of day, day of week, and month of year, were also obtained. Annual average concentrations about each airport, using characteristic stability wind rose data, were computed for those pollutants which have annual national standards of ambient air quality (particulates, NO_2 , and SO_2). Annual average concentrations were also computed for lead. Short-term maxima concentrations about each airport were computed, using the specified averaging times for those pollutants which have national maxima standards of ambient air quality (particulates, CO, SO_2 , and non-methane hydrocarbons). Short-term maxima concentrations were also computed for NO_2 . The final subtask of the air quality analysis was to evaluate the effectiveness of various control techniques specified in the companion program (Ref 6). A modified set of emission factors was developed for each control technique. The effect of the modified emission factors on the emission rates and concentrations of appropriate airports was then computed.

The fourth task, future projections, was divided into two subtasks. In the first subtask, emission rates at the selected airports were computed for the years 1975 and 1980, based on projected aircraft activity. In the second subtask, annual average concentrations were computed about one air-carrier airport for the years 1975 and 1980. This enabled projections of the concentrations at the remaining airports to be estimated.

The final task, unburned fuel emissions, was also divided into two subtasks. In the first subtask, the practices of airlines with respect to disposal of unburned fuel were examined and the total annual emissions of unburned fuel for the air-carrier airports were calculated. In the second subtask, the distribution around an airport of maxima surface concentrations was computed. These concentrations were then compared to the national standard of ambient air quality for non-methane hydrocarbons (based on the assumption that the vented fuel completely vaporized) to evaluate their importance.

Report Contents

The principal results and conclusions of the program are summarized in the following section of the report. Detailed descriptions of the methodology and results of the analyses of emission rates and impact at the selected airports are contained in later sections.

The computer program which was used to calculate the emission rates and impact is described in a separate report (Ref 7). The companion report on control technology (Ref 6) also is recommended as a source of related information.

SUMMARY OF RESULTS

General Nature of the Results

The principal results of this program consist of predicted values of pollutant emission rates at selected airports and resulting concentrations of pollutants for specific time periods and locations in the vicinity of these airports. Development of these predictions required the use of a wide variety of data and rather complex mathematical modeling techniques. Due to the many aspects of the problem, a number of compromises were necessary to keep the program within reasonable bounds. These compromises were made in the quality of engine emission data, aircraft operating cycle data, emission data and modeling of the airport surroundings, and modeling, in general, of line and area emission sources, among others. Another important compromise was the absence of a coordinated measurement program for calibration of the predicted concentrations. Thus, there are many sources of uncertainty in the results which have been obtained and no definitive means of identifying the magnitude of the uncertainties.

Notwithstanding these uncertainties, the predictions of aircraft emission rates and their impact on air quality are considered to be indicative of the existing situation at the selected airports and other similar airports. In the opinion of the authors, these results provide a valid basis for evaluating both the impact of aircraft emissions and the need for emission controls.

The complete results are summarized below according to the specific objectives of the program as presented in the INTRODUCTION. Later sections of the report present the results in greater detail.

Selection of Airports

The airports which were selected for air quality analysis in this study are:

Air-Carrier

- Los Angeles International Airport (LAX)
- Washington National Airport (DCA)
- J. F. Kennedy International Airport (JFK)
- Chicago-O'Hare International Airport (ORD)

General Aviation

Van Nuys Airport, California

New Tamiami Airport, Florida

It is felt that the aircraft emissions at these airports represent the greatest potential impact upon air quality of the various types of civil airports in the United States.

Aircraft Emission Factors and Airport Characteristics

Emission Factors

Emission factors have been defined in a manner such that the same emission data may be used for all airports. Values of these emission factors have then been calculated for aircraft and other sources of pollution. These values appear in tables which are presented in the section on emission factors. The other sources of pollution considered are motor vehicles, heating plants, and fuel storage areas within an airport, and the airport surroundings.

Aircraft emission factors were subdivided according to pollutant type, aircraft class, and mode of operation. The subdivisions which were used are:

<u>Pollutant Type</u>	<u>Aircraft Class</u>	<u>Mode of Operation</u>
Carbon Monoxide	SST	Approach
Nitrogen Oxides	Jumbo Jet	Landing
Sulfur Dioxide	Long-Range Jet	Taxi
Particulates	Medium-Range Jet	Idle & Shutdown
Lead	Turboprop Transport	Maintenance
Total Hydrocarbons	Business Jet	Start-up & Idle
Reactive Hydrocarbons	Utility (Piston Engine)	Delay at Runway
Aldehydes	Military:	Take-off
	Over 400,000 lbs	Climb-out
	100,000 to 400,000 lbs	Fuel Venting
	10,000 to 100,000 lbs	
	Under 10,000 lbs	
	Helicopter and V/STOL	

Emission factors for the approach, idle and shutdown, maintenance, start-up and idle, climb-out, and fuel venting modes have been characterized as total emissions of pollutant per aircraft. Since taxi and delay times vary from airport to airport, emissions factors for these modes have been characterized as emission rates of pollutant per aircraft. Finally, two emission

factors have been used to characterize both the landing and take-off modes by linear variations of emissions of pollutant per aircraft per unit distance traveled.

The aircraft emission factors are based upon measured emission rates for specific engines. In most cases, the engine selected to represent an aircraft class is the most widely used engine in that class. Since measured emission rates of reactive hydrocarbons were not generally available, emission factors for this pollutant type are far from complete. Further, since engine emission rates and operational data were generally not available for military aircraft, emission factors of corresponding civil classes were substituted.

Emission factors for the other sources of pollution in the vicinity of an airport have also been subdivided according to the pollutant types listed above. For motor vehicle travel within the airport, the emission factors have been characterized as emissions of pollutant per vehicle per distance traveled. Emission factors for heating plants, on the other hand, were further subdivided according to type of heating fuel. The heating fuels which were considered are: fuel oil, natural gas, LPG butane, LPG propane, bituminous coal, and anthracite. The emission factors have been characterized as emission rates of pollutant per fuel flow rate. In the case of fuel storage areas, emission factors were associated with specific airports. These emission factors have been characterized as emission rates of pollutant per fuel storage area. Finally, emission factors for airport surroundings were further subdivided according to type of surroundings. The surroundings which were considered are: city center, urban, suburban, semi-rural, rural, cemetery, park, and airport.

Airport Characteristics

Two types of data have been acquired for the selected airports: data necessary to calculate pollutant emission rates in the airport vicinity, and data necessary to calculate the concentrations which result from dispersion of the pollutants. The data appear in tables and figures which are presented in the section on airport characteristics, or in the case of the meteorological observations, the source of the data is given.

The data which has been compiled to calculate pollutant emission rates consist of:

1. Aircraft activity by hour of day, day of week, month, and year.
2. Aircraft activity by aircraft class.
3. Aircraft taxi and delay times.
4. Average automobile travel within the airport and average number of automobiles per passenger.
5. Heating plant fuel type, rating, and activity.
6. Emission rates of fuel storage facilities.
7. Nature of the airport surroundings.

The data which has been compiled to calculate the concentrations of pollutants which result from dispersion of airport emissions, consist of:

1. Airport layouts which give the locations of terminals, taxiways, runways, hangars, roadways, heating plant, and fuel storage areas.
2. Aircraft activity by runway, terminal, and hangar.*
3. Locations of the various features (such as urban or suburban areas, or parks) of the airport surroundings.
4. Relative frequencies of all combinations of wind speed class, wind direction sector, and atmospheric stability based on airport observations at three-hour intervals for 1965 to 1969 inclusive.
5. Local meteorological observations at three-hour intervals for 1970, including wind speed, wind direction, cloud cover, ceiling, and temperature.
6. Morning and afternoon mixing heights of the atmosphere.

The first three listed items are required to locate the various sources of emission and to select receptor locations at the airport. The latter three listed items are the meteorological data required to analyze the

* Aircraft activity by terminal and hangar are indirectly specified by airline activity.

dispersion of emissions from individual sources. The fourth item above is used to calculate long-term (for example, annual) pollutant concentrations. On the other hand, the fifth item is used to calculate short-term (for example, 24-hour) pollutant concentrations.

Air Quality Analysis

Model of Airport Emissions and Atmospheric Dispersion

Analysis procedures were developed to calculate pollutant emission rates at airports and the resulting concentrations in the airport vicinity. These procedures were subsequently incorporated into a single computer program (Program AIREC) written in the Fortran language.

Emissions at an airport have been modeled by a large number of continuous point sources of constant strength which are distributed throughout the airport and its surroundings. The sources are located in the following manner:

1. Aircraft emissions during the start-up and idle, and idle and shutdown modes at the terminals.
2. Aircraft emissions during the taxi mode at stations which divide each taxiway into a number of equal segments.
3. Aircraft emissions during the delay-at-runway mode at the heads of the runways.
4. Aircraft emissions during the landing and take-off modes at stations which divide each runway into a number of equal segments.
5. Aircraft emissions during the approach and climb-out modes at stations which divide a single approach and climb-out path for each runway into a number of segments which become successively larger as distance from the airport increases.

6. Aircraft emissions during the fuel-venting mode at a single point on the climb-out path of each runway.
7. Aircraft emissions during the maintenance mode at the hangars.
8. Motor vehicle emissions at stations which divide each roadway (including the parking areas) into a number of equal segments.
9. Heating plant emissions at the heating plants.
10. Fuel storage emissions at a point within each storage area.
11. Surrounding emissions at a point within each subdivision of the surroundings.

The strength of each point source of emissions is calculated from the emission factors and airport characteristics provided as input data.

The basis of the modeling of atmospheric dispersion is the empirical double-Gaussian plume solution to the diffusion equation. The solution is for a steady-state continuous point source in a wind of non-zero magnitude. The plume spread in the vertical and crosswind directions is Gaussian in form and is dependent upon downwind distance from the source and atmospheric stability. Eventually the trapping effect of the upper limit to vertical mixing (the mixing height) restricts the vertical plume spread and modifies the solution. In the calculation of short-term concentrations, this dispersion model is applied to a single set of meteorological conditions. In the calculation of long-term concentrations, the fact that there is a distribution of meteorological conditions is used to simplify the basic dispersion model. The result, known as the Martin-Tikvart model, approximates plume spread in the crosswind direction and sums the contributions of all combinations of wind speeds and atmospheric stabilities.

The concentration at any receptor point is obtained as the sum of the contributions from each point source of emissions. The representation of a line or area emission source at an airport by one or a number of point sources results in inaccuracies which increase with proximity to the source. The magnitude of the inaccuracy for a specified distance between receptor and source point depends on the physical dimensions of the actual source.

Greater detail on the model of airport emissions and atmospheric dispersion, including the actual dispersion equations, are presented in the section on modeling.

Emissions at the Selected Airports

Emissions of the various pollutants have been calculated at the selected airports for a number of different situations. The values appear in tables which are presented in the section on emission rates.

Annual emissions for the year 1970 at the air-carrier airports revealed the following features:

1. Aircraft sources contribute the following percentages of total pollutant emissions at the air-carrier airports:

	<u>Low</u> <u>Percentage</u>	<u>High</u> <u>Percentage</u>
Carbon Monoxide	47 (JFK)	59 (DCA)
Nitrogen Oxides	26 (JFK)	59 (DCA)
Sulfur Dioxide	32 (DCA)	93 (ORD)
Particulates	87 (JFK)	93 (LAX)
Lead	1 (ORD)	11 (DCA)
Total Hydrocarbons	61 (DCA)	77 (LAX)

2. Carbon monoxide contributes the largest amount of emissions to the total emissions at an air-carrier airport, followed generally by total hydrocarbons, nitrogen oxides, either sulfur dioxide or particulates, and lead.
3. General aviation airports have much lower emissions of total hydrocarbons, nitrogen oxides, sulfur dioxide, particulates, and lead than the air-carrier airports. In the case of carbon monoxide, however, Van Nuys was found to have about 60 per cent of the total emissions of DCA.

The variation of emissions with month of year, day of week, and hour of day was found to reflect very closely the variation in aircraft activity.

Examination of aircraft emissions by mode revealed the following:

1. The taxi mode is the biggest contributor to carbon monoxide, lead, and total hydrocarbon emissions.
2. The predominant part of nitrogen oxide, sulfur dioxide, particulate, and aldehyde emissions occurs during the approach and climb-out modes.
3. The take-off mode is an important contributor to nitrogen oxide, sulfur dioxide, and particulate emissions.
4. Other important contributors are: the idle-at-runway mode (carbon monoxide, lead, and total hydrocarbons), the taxi mode (sulfur dioxide), and the fuel-venting mode (total hydrocarbons).

Impact Analysis of the Selected Airports

Concentrations of the various pollutants have been calculated at each of the selected airports for comparison with air quality standards. Both annual average values and short-term maxima values of concentration for a large number of receptor locations appear in tables which are presented in the section on impact analysis.

It was found that the national primary and secondary ambient air quality standards for particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, and non-methane hydrocarbons, respectively, were exceeded at a number of the selected air-carrier airports. However, when consideration was limited to receptors located in "reasonable access" areas (which are defined as areas to which the general public has reasonable access for the averaging time specified in the air quality standard for the pollutant), quite a different result was found. For both the national primary and secondary ambient air quality standards, the assumed "reasonable access" areas for each time period are listed below:

1. Annual period - residential areas in the airport vicinity.
2. 24-hour period - residential areas in the airport vicinity.
3. 8-hour period - residential areas, terminals.
4. 3-hour period - residential areas, terminals, airport boundaries, waterways.
5. 1-hour period - residential areas, terminals, airport boundaries, waterways, areas adjoining roadways.

For particulates and sulfur dioxide, aircraft contributions were found to

be small at those receptors in "reasonable access" areas which exceeded the appropriate air quality standards. On the other hand, a different result was obtained for nitrogen dioxide, carbon monoxide, and non-methane hydrocarbons. Aircraft emissions of nitrogen dioxide were found to be somewhat significant at receptors in "reasonable access" areas which exceeded the annual standard. The maximum aircraft contribution was 19 per cent of the standard, and there is reason to believe the value could be as high as 40 per cent. Aircraft emissions of carbon monoxide contributed significantly to receptors in "reasonable access" areas which exceeded the 8-hour and 1-hour air quality standards. The maximum aircraft contribution was 210 per cent of the 1-hour standard. Aircraft emissions of non-methane hydrocarbons contributed greatly to receptors in "reasonable access" areas which exceeded the 6 am - 9 am air quality standard. There are a number of receptors for which the aircraft contribution, by itself, is an order of magnitude larger than the standard. However, it should be recognized that this standard is a guide to achieving the oxidant standard. Lead was not found to occur in potentially harmful concentrations at any receptors in "reasonable access" areas.

Aircraft emissions at general aviation airports were not found to exceed air quality standards under any circumstances. However, concentrations of lead are significant and the potential for exceeding air quality standards of carbon monoxide seems to be present.

Effectiveness of Control Techniques

The effectiveness of the following control techniques has been investigated:

1. Combustion chamber redesign (minor).
2. Combustion chamber redesign (major).
3. Divided fuel supply system.
4. Water injection.
5. Methods applicable to future engines.
6. Catalytic reactors for piston engines.
7. Increase in idle speed and reduction of number of engines used.
8. Use of tractors to move aircraft in ground operations.

Values of engine emission indexes (where applicable), aircraft emission factors, and percentage change of aircraft emissions and resulting concentrations for the various control methods are given in tables which

are presented in the section on controls.

The following conclusions concerning emission control for turbine-engine aircraft at air-carrier airports were drawn:

1. Minor modifications of combustion chambers will provide large reductions in total hydrocarbon and particulate concentrations, and a lesser reduction in carbon monoxide concentrations.
2. Minor modifications in ground operating procedures will further reduce carbon monoxide and total hydrocarbon concentrations, but will increase particulate concentrations.
3. Simultaneous reductions in concentrations of carbon monoxide, total hydrocarbons, nitrogen oxides, and particulates can only be achieved through a combination of combustor modifications and other engine modifications, or by adopting new concepts of combustion chamber design.

For piston-engine aircraft at general aviation airports, control devices developed for automobile engines could produce large reductions in carbon monoxide and total hydrocarbon concentrations. These devices may require low-lead gasoline, thereby reducing lead concentrations as well.

Future Projections of Emissions and Impact

Projections of uncontrolled emissions of the various pollutants were calculated for the years 1975 and 1980 at each of the selected airports except New Tamiami (which lacked reliable activity projections). When compared to 1970 emissions, the most dramatic trends revealed by the 1980 projections were:

1. A 200 per cent increase in nitrogen oxide emissions and a 60 per cent decrease in total hydrocarbon emissions from aircraft sources at the air-carrier airports.
2. A 40 per cent increase in nitrogen oxide emissions, a 30 per cent decrease in carbon monoxide emissions, a 60 per cent decrease in total hydrocarbon emissions, and the virtual elimination of lead emissions from all sources within the air-carrier airports.
3. A 140 per cent increase in lead and carbon monoxide emissions

from aircraft sources at the general aviation airport.

4. About a 100 per cent increase in lead and carbon monoxide emissions from all sources at the general aviation airport.

Annual average concentrations were calculated for the years 1975 and 1980 at LAX. The values indicated that changes in concentrations due to aircraft sources follow quite closely the changes in aircraft emissions. Hence, the above trends for aircraft emissions can be extended to concentrations resulting from aircraft emissions.

Analysis of Unburned Fuel Emissions

Total hydrocarbon emissions due to fuel venting were calculated for the year 1970 at each of the selected air-carrier airports. The values ranged from a low of 120,000 kg at DCA to a high of 460,000 kg at ORD.

Concentration isopleths were calculated at DCA for a one-hour period of heavy activity with weather conditions which are conducive to large concentrations. A peak ground concentration of $18 \mu\text{g}/\text{m}^3$ was found, together with a 500,000 sq m area subjected to concentrations over $10 \mu\text{g}/\text{m}^3$. Hence, it was evident that fuel venting, by itself, gives rise to fairly low levels of total hydrocarbon concentrations.

Conclusions

At the present time, predicted concentrations of total hydrocarbons and carbon monoxide due to aircraft emissions exceed their respective national ambient air quality standards at locations in the vicinity of major air-carrier airports. Although predicted concentrations of nitrogen dioxide due to aircraft emissions alone do not exceed the standard, they can contribute significantly to excessive concentrations. On the other hand, although air quality standards for particulates and sulfur dioxide are exceeded in airport vicinities, aircraft contributions are small in reasonable access areas. Predicted concentrations of lead due to piston-engine aircraft at major general aviation airports are significant, although they do not presently exceed the level associated with increases in blood-lead levels.

Future projections of uncontrolled emissions through 1980 indicate that nitrogen oxide emissions will rise sharply, while total hydrocarbon

emissions will drop significantly. However, in 1980, concentrations of total hydrocarbons and carbon monoxide are still projected to exceed the national air quality standards in the vicinity of air-carrier airports. Activity at general aviation airports is projected to undergo a large increase through 1980. This may result in carbon monoxide concentrations which exceed the national air quality standard, and lead concentrations which exceed the level associated with increases in blood-lead levels in the future at general aviation airports.

Based on preliminary estimates of emission control effectiveness for various control methods, some of which have not been developed or tested, large reductions in concentrations of carbon monoxide, total hydrocarbons, nitrogen oxides, and particulates due to emissions of turbine-engine aircraft can be achieved. Similarly, control devices developed for automobile engines and low-lead gasoline can produce large reductions in concentrations of carbon monoxide, total hydrocarbons, and lead due to emissions of piston-engine aircraft.

Finally, the practice of fuel venting gives rise to considerable total hydrocarbon emissions, but these emissions result in fairly low ground-level concentrations.

SELECTION OF AIRPORTS

Introduction

The first task of the study was the selection of specific airports for which detailed analyses of emissions and their impact were conducted. The results of this airport selection task are presented below, along with the bases used for selection and lists of alternative candidate airports.

Selection Criteria

The primary objective in selecting airports for study was to identify, as far as possible, those airports which cause the greatest impact of emissions from aircraft activities. Factors considered in evaluating the potential impact of individual airports were:

1. Aircraft activity level.
2. Proximity of airport boundaries.
3. Wind speed.

Activity level was used as the primary selection criterion since it is directly related to the total quantities of pollutants emitted. Airport boundary proximity was approximated by the square root of the airport area. This factor was used as a measure of the distance allowed for dilution of emissions prior to their encounter with receptors at the airport perimeter. Similarly, the mean annual wind speed was used as an approximate measure of the dilution rate of aircraft emissions associated with local meteorological conditions.

Airport activity levels were taken from FAA air traffic activity reports (Refs 8 and 9). Airport areas were measured from maps of the airport communities. The areas used may not be the official areas actually under the control of the airport operators. However, the areas used appeared to be reasonable approximations of the areas which are devoted to activities associated with airport operations. Local wind speeds were taken from Reference 10.

These three factors were combined to form an "impact index" as follows:

$$I \equiv \frac{N}{\sqrt{AS}}$$

where I = impact index

N = aircraft operations per year

A = airport area, sq mi

S = mean annual wind speed, mph.

This index was defined and used strictly for this airport selection task; it is regarded as, at best, an approximate indicator of impact.

In addition to the above factors, consideration was given to the availability of data on aircraft activities and secondary emission sources at specific airports. This factor proved to be particularly important in the selection of military airports and was the basis for modifications of the selections.

Candidate Airports

Lists of air-carrier, general aviation, and military airports from which the selections were made are contained in Tables 1, 2, and 3. The relevant selection factors are shown in the tables wherever they were available. Joint civil-military airports were not considered since such airports are few in number and the impact of emissions from joint civil-military activities can be deduced readily from analyses of civil and military airports.

Airports Selected for Initial Study

Ten airports were selected for initial study, including air-carrier, general aviation, and military airports. The airports are listed below:

Air-Carrier

Los Angeles International
Washington National
J. F. Kennedy International
O'Hare International

General Aviation

Van Nuys, California
Tamiami, Florida

Military

Vance AFB, Enid, Oklahoma

Laredo AFB, Laredo, Texas

Fort Rucker, Alabama

Corpus Christi NAS, Corpus Christi, Texas

The rationale for each of the airports selected for study is discussed briefly in the following paragraphs.

Los Angeles was selected primarily because of its high impact potential as indicated by the index. An additional factor, however, is the availability of a detailed study on emissions and air quality which has been conducted for this airport (Ref 11).

Washington National also was selected because of its high impact index and because of a detailed impact analysis being conducted at that airport under FAA sponsorship*.

J. F. Kennedy was selected primarily because of the availability of air quality data taken in the airport vicinity (Refs 12 and 13), as well as very detailed activity data. It should be noted, however, that the air quality data was of no utility in confirming calculated pollutant concentrations.

Chicago-O'Hare was selected entirely on the basis of its high aircraft activity level.

Van Nuys Airport was selected because of its high impact index, as well as its high activity level. Its selection was also influenced by the availability of relatively detailed aircraft activity data.

Tamiami Airport was selected because of its high traffic level and its high impact index for general aviation airports outside of California.

Vance AFB and Laredo AFB were selected on the basis of high activity levels.

Fort Rucker was also selected because of its high activity level. It is an army facility which apparently is used primarily for helicopter operations. Because of the uniqueness of its activities, however, there was doubt that it would be a useful candidate for this program.

* Contract No. DOT-FA71WA-2659.

Corpus Christi NAS was selected because of its high aircraft activity level. The auxiliary air stations, designated by NAAS, were not selected because the operations at these airports probably consist largely of touch-and-go practice carrier landings. The operations would result in emission rates quite different from those at conventional air terminals. However, since the Kingsville (Texas) NAAS is close to Corpus Christi, a preliminary analysis of both stations was considered.

Airports Selected for Complete Analysis

An attempt was made to gather aircraft operations and activity data, airport plans, and data on secondary emission sources for the ten airports initially selected. It soon became apparent that the amount of time required for data acquisition at the military airports was beyond the limitations of this study, if such data could be obtained at all. Consequently, military airports were dropped from consideration, for the present study. The six remaining airports were selected for complete analysis; the airports are:

Air-Carrier

Los Angeles International Airport (LAX)
Washington National Airport (DCA)
J. F. Kennedy International Airport (JFK)
Chicago-O'Hare International Airport (ORD)

General Aviation

Van Nuys Airport, California
New Tamiami Airport, Florida

AIRCRAFT EMISSION FACTORS

Introduction

Emission factors have been determined for aircraft in current use and, as far as possible, for future aircraft. The pollutants which were considered are: carbon monoxide, nitrogen oxides, sulfur dioxide, aldehydes, reactive hydrocarbons, total hydrocarbons, lead, and particulates. The steps which were taken to obtain the emission factors are listed below:

1. The NREC aircraft classification system (Ref 1) was modified to include new and prospective types of aircraft and to exclude aircraft which no longer are present in sufficient numbers to merit inclusion. Additional classes for military aircraft were added.
2. Existing data on engine emission rates were supplemented with recent measurements.
3. Operational cycles were defined for each aircraft class for airborne operations and for ground operations based on information from various sources.
4. Airport emissions other than those from aircraft engines (automobiles, auxiliary equipment and other sources) were also analyzed.
5. The emission data and operational cycles were combined to provide emission factors for aircraft in each class during the complete operational cycle.

Aircraft Classification System

The classification system devised in Reference 1, based on the air-pollutant emission potential of civil aircraft, has been modified for this study and is shown in Table 4. Column one of the table gives the aircraft category. Columns two and three give the new and old (Ref 1) classifications. Columns four and five give aircraft types and one or two examples of the aircraft in that class. The next three columns provide the details of a representative engine. The engines selected for the air-carrier and general aviation classes represent those in greatest use, while the engines of classes 8, 9, and 10 are military versions of civil engines. The final column of Table 4 provides a value for the number of engines per aircraft.

Twelve classes of aircraft have been identified for each of which an average emission factor per aircraft was estimated. These classes fall into the four general categories of air-carrier, general aviation, military, and V/STOL. The category comprising military aircraft is an addition to those used in Reference 1. V/STOL aircraft have been placed in a category of their own rather than including them in each of the first three categories.

Considering first the air-carrier category, it will be observed that two additional classes have been included to cover the jumbo jet transports and the supersonic transports. While a case could be made for combining these two classes, it was felt to be of value to separate them and thus show their relative importance as sources of pollutants. Class 5 of Reference 1, piston engine transports, has been omitted. Adequate justification for this may be found in the fact that, of all the domestic departures from Chicago-O'Hare International Airport for the year ending June 1969, only one per cent were piston engine transports. Moreover, the current value should be a significantly lower percentage.

The general aviation classes are unchanged from Reference 1, but the military category is an addition, felt to be necessary since military airports were to be considered in the study. The method of defining the military classes by weight was decided on as directly relating to power and hence to pollutant emission levels. The classes defined may in some cases also be related to the air-carrier and general aviation classes. Due to the limited time of the program and the problems of obtaining information on military aircraft, this could have been beneficial in the analysis of military airports.

Aircraft Engine Pollutants

Aircraft engine pollutants considered in this study are discussed below.* Further information on each of the pollutants may be obtained from Reference 1.

* Odors resulting from the operation of aircraft engines are noticeable at airports and are objectionable. Since, at present, the substances causing the odor have not been precisely identified, odor cannot be explicitly considered in this study. It is expected, however, that odor reduction will accompany a decrease in the level of "total hydrocarbon" emissions.

Carbon Monoxide

Carbon monoxide is a colorless, odorless, toxic gas, frequently formed during oxygen deficient combustion. The formation of carbon monoxide is also dictated by reaction kinetics as in the case of gas turbine combustors.

Nitrogen Oxides

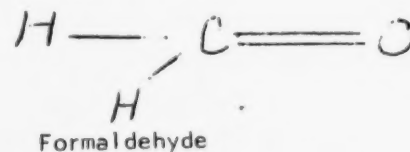
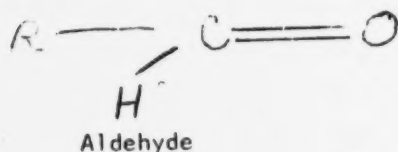
The principle oxide of nitrogen formed during the burning of fuel is nitric oxide (NO). It is formed by the oxidation of nitrogen at high temperatures. Most oxides of nitrogen react in the atmosphere to form nitrogen dioxide (NO₂). In this study, all emission rates and ambient concentrations of nitrogen oxides (NO_x) are reported as though all the nitrogen present had combined to form NO₂.

Sulfur Dioxide

Sulfur dioxide is a stable compound which neither burns nor supports combustion. It is a colorless gas with a pungent odor. It combines with water to form sulfurous acid and is therefore an acid anhydride. In the presence of certain catalysts and oxygen, it may be oxidized to sulfur trioxide and thence hydrogenated to sulfuric acid.

Aldehydes

An aldehyde is a carbonyl compound having one alkyl group (R) attached to the carbonyl function. Formaldehyde is an exception in that it carries two hydrogen atoms and no alkyl groups.



Aldehydes are generally formed from the partial oxidation of alcohols. Since photochemical oxidation of unsaturated olefinic hydrocarbons results in the formation of formaldehyde, acrolein, acetaldehyde, propanaldehyde, and isobutylaldehyde, these should be present in polluted air. Of these, formaldehyde appears to be the most prevalent.

Aldehydes are odorous substances, and even at low concentrations, several of them are very irritating to the eyes and to mucous membranes.

Hydrocarbons

The formation of photochemical smog involves the oxidation of the reactive hydrocarbons present in the atmosphere. Olefins, such as those found in unburned fuel, are quite reactive, while benzene is less so. Methanes and the alkanes are practically nonreactive. To indicate the important smog-producing hydrocarbons, a separate category of reactive hydrocarbons has been considered. This includes all hydrocarbons except methane and the other alkanes.

Emission rates and ambient concentrations of the quantity referred to in this study as "total hydrocarbons" may include some amount of aldehydes and other highly oxygenated compounds in addition to true hydrocarbons.

Lead

The aviation gasoline used by aircraft piston engines contains tetraethyllead and halogenated scavenging agents in quantities similar to those in automotive gasoline. Lead compounds in the form of particulate matter are formed during the decomposition of these additives.

The toxicity of lead and lead compounds is well known, and a basis is being sought for the establishment of an air quality standard with respect to lead compounds.

Particulates

All particulates emanating from an aircraft engine exhaust might be considered in the definition of particulate emissions. Thus, the Los Angeles County Air Pollution Control District defines particulate matter as any substance, solid or liquid, except unbound water, that exists in a finely divided form at standard ambient conditions (Ref 14). This definition may result in hydrocarbons being placed in two categories. In this study, consideration was limited by the large majority of engine emission data to dry particulates. For piston engines, dry particulates mainly consist of lead emissions.

Engine Emission Data

The data on aircraft engine emissions is presented in Table 5. This table is subdivided into Tables 5a, b, c, and d, each of which present the engine emissions for a different mode of engine operation and power, namely: idle, approach, take-off, and cruise. The table has been set out similarly to Table XLI of Reference 1, but additional categories have been included. As in Reference 1, the actual engine types have not been revealed, but a similar letter designation has been used.

The first column of Table 5 gives the aircraft class and the second column gives the type of engine, e.g. turbojet, and the designation used for it in this report. Columns three to five contain details of fuel, fuel-to-air ratio, and fuel flow rate in kgms per hr. The remaining eight columns give values for the emission index defined as gms per 1000 gms of fuel, for each of the pollutants: CO, NO₂, SO₂, aldehydes, reactive hydrocarbons, total hydrocarbons, lead, and particulates.

Aircraft Operational Cycle

To analyze the pollutant emissions occurring during operations at airports, an enlarged form of the "landing-take-off cycle" of Reference 1 has been devised. This enlarged cycle takes into account all operations which will contribute significant quantities of emissions to the environs of the airport. One such complete cycle will take place for every two operations as defined by the FAA. As in Reference 1, aircraft emissions above an altitude of 900 meters have not been included in the operational cycle. Emissions above 900 meters are considered to be prevented from contributing to ground-level concentrations by the presence of the mixing layer.

The aircraft cycle is subdivided, firstly into the take-off and landing operations which are tabulated for the aircraft classes in Table 6. The second subdivision is concerned solely with the problem of fuel venting during aircraft ascent, which normally occurs at about 600 meters, and is tabulated in Table 7 by aircraft class. The third subdivision concerns ground operations defined as start-up and idle, idle and shutdown, maintenance, taxi, and delay at runway. The times for some of the operations

in the third category are airport dependent and data for these will be given later.

LTO Cycle Subdivision

Within this part of the cycle, the following operations are included:

- Approach from 900 meters
- Landing run
- Take-off run
- Climb-out to 900 meters

Apart from the landing mode, engine operating conditions and pollutant emission rates remain relatively constant. For the landing run, the use of full power for reverse thrust occurs. Since this occurs for only a few seconds (about 6) it will be ignored in this study. It will be assumed that the landing run takes place with engines at idle. Performance characteristics during the LTO subdivision for the twelve aircraft classes is given in Table 6a and b. For these tables, values from Reference 1 have been updated using mean values of the typical aircraft cited in Table 1 from References 15 and 16.

Fuel Venting

Recently, considerable concern has been shown in the operation of fuel venting or drainage. At engine shutdown, drainage from the fuel manifold is collected in a drain tank in each engine nacelle (Ref 17). This results from the method by which a rapid fuel cut-off at shutdown is achieved. It also minimizes a buildup of carbon due to residual fuel trapped in the manifold. At start-up, a little more fuel is added to this quantity before the dump valve is closed.

During the following aircraft ascent after take-off, the fuel collected is purged out of the drain tank by the ram air pressure, as a sufficient speed is achieved (Ref 17). This speed for most aircraft is about 200 knots and this occurs at a height of about 600 meters (Ref 18). Table 7 gives typical amounts of fuel vented by aircraft for the classes in use by the air carriers (Ref 17).

Ground Operations

The final aspect of the aircraft cycle concerns the operating modes of taxiing, idle and shutdown, maintenance, start-up and idle, and idle at runway. With the exception of the maintenance mode, the aircraft operations indicated by these modes are self evident. The maintenance mode is defined to be operation of the aircraft engines in the hangar area between flights as part of a regular maintenance schedule.

The emissions resulting from each of these modes is taken as that for engine idle conditions. These will be obtainable from Table 5a. The idle and shutdown, start-up and idle, and maintenance modes will be related only to the aircraft class, and the times for these operations are given in Table 7. The idle at runway and taxi mode are dependent on the particular airport as well as on the aircraft class. Thus, time periods for this latter group will be included in the airport specifications.

Helicopters and V/STOL

Lacking additional information, the behavior of helicopters and V/STOL aircraft as defined in Reference 1 has been followed. Thus, a typical trip length of 13 minutes duration has been assumed to take place below 900 meters. This period has been equally assigned to the climb-out and approach operational modes. It is assumed that no time is spent in operations corresponding to the take-off and landing runs of fixed-wing aircraft.

Other Emissions

In this section, other sources of emission apart from aircraft engines are considered. Specifically, we consider emissions from aircraft auxiliary power units, automobiles, the airport heating plant, fuel storage losses, the operation of service equipment, and the airport surroundings.

Auxiliary Equipment

The emissions from aircraft auxiliary equipment has been the subject of a special study (Ref 19). Preliminary data of the study were just becoming available during the determination of aircraft emission factors.

Emission levels for two operating conditions of a typical unit are given in Table 8a. The times of operation of the auxiliary power unit during a typical cycle are given in Table 8b. The emissions which result from the combination of these two tables are less than 5 per cent of the main engine emissions during the complete operational cycle. Therefore, given the preliminary nature of the auxiliary power unit emission data, they have not been incorporated into the total emissions of the aircraft.

Automobiles and Service Vehicles

Pollution from these sources may be obtained from a knowledge of the emissions per mile, the mileage which occurs per day within the airport, and the principal roads and operational areas of the vehicles. The mileage which occurs per day within the airport, and the principal roads and operational areas of the vehicles are included in the airport specifications. The emissions from automobiles and other ground vehicles is given in Table 9. In this table, emission values are tabulated for present and future conditions (Refs 20 and 21). The units for these emission factors are grams per kilometer.

Airport Heating Plant

The airport heating plant represents a substantial source of emissions and must be considered in the study of airport emissions. Table 10 details the emissions for various types of heating plants. Thus, the first column identifies the type of heating plant by the fuel used and the second column specifies the units in which the pollutants are measured. The source of this information is Reference 20. The types of fuel used and the fuel flow rate will be tabulated for each of the airports under consideration.

Fuel Storage Losses

The airport fuel storage tanks represent a significant source of hydrocarbon emissions. The emissions depend upon many factors, including the type of tank (fixed or floating roof), tank diameter, type of fuel, and the possible use of vapor recovery systems. Hence, the emissions will be specified in the airport characteristics. The units will be grams of pollutant for each fuel storage area per unit time.

Airport Surroundings

Values of the emission indexes for the areas surrounding airports are most suitably related to individual airports and will therefore be included in the section on airport characteristics.

Emission Factors

The engine emission data and the definition of the aircraft operational cycle are combined to provide emission factors for each aircraft class during each mode of operation. For this purpose, the engine data was first reduced to a typical set of indexes for each aircraft class. The selected sets of data are given in Table 11. In each case, the data sets are those which are felt to be the most reliable and complete set for a typical engine in the aircraft class. The preferred fuels for which the emission data were taken were Jet A1 followed by JP5. Of necessity, the emission indexes for aircraft in class 2 are a combination of two separate sets of values. Also, the values for aircraft class 12 were taken from Reference 1.

The emission indexes of Table 11 were then applied to each part of the operational cycle to obtain the emission factors in Table 12. The emission factors are presented by mode of operation, with a set of factors given for each aircraft class. Each emission factor is per aircraft. The details of the calculation of the emission factors are described below for each mode of operation:

1. Idle and Shutdown, Start-up and Idle Modes (Table 12a and b).

Table 7 lists the time spent in each of these modes by each aircraft, while Table 11a gives the emission index. Using the modal times and the emission indexes, the emission factor is calculated from the following relationship:

$$\text{Emission Factor, gm} = E_i M_i T N$$

where E_i = emission index at idle power, gm per kgm
 M_i = fuel flow rate at idle power, kgm per sec
 N = number of engines per aircraft in specified class
 T = modal time, sec.

The modal time for various aircraft classes for these two modes are summarized below:

Mode	<u>Idle and Shutdown</u>								<u>Start-up and Idle</u>	
	1	2	3	4	5	6	7	12	All Except 12	12
Aircraft Class										
Modal Time (secs)	15	15	30	15	15	5	5	0	60	0

2. Maintenance Mode (Table 12c). The emission factor for this mode is given by

$$\text{Emission Factor, gm} = N(E_i M_i T_i + E_c M_c T_c)$$

where E_c = emission index at cruise power, gm per kgm

M_c = fuel flow rate at cruise power, kgm per sec

T_i = modal time at idle power, 69 secs

T_c = modal time at cruise power, 23 secs.

3. Idle at Runway Mode (Table 12d). The emission factor is expressed as a rate, since duration of this mode varies from one airport to the next. The governing equation is

$$\text{Emission Factor, gm per sec} = E_i M_i N$$

4. Taxi Mode (Table 12d). The emission factor for this mode is calculated in the same manner as that of the Idle at Runway Mode.
5. Approach and Climb-Out Modes (Tables 12e and 12f). The emission factors for these modes are calculated from Tables 5b and 5c, and 6a and 6b. For the approach mode, the equation used is

$$\text{Emission Factor, gms} = E_a M_a T_{ab} N$$

where E_a = emission index at approach power, gm per kgm
 M_a = fuel flow rate at approach power, kgm per sec
 T_{ab} = time spent in approach mode, sec .

In the climb-out mode, the governing equation applicable for all aircraft classes except 12 is

$$\text{Emission Factor, gm} = E_{to} M_{to} T_{ef} N$$

where E_{to} = emission index at take-off power, gm per kgm
 M_{to} = fuel flow rate at take-off power, kgm per sec
 T_{ef} = time spent in climb-out mode, sec .
 For aircraft class 12, the emission factor is calculated from

$$\text{Emission Factor, gm} = E_{co} M_{co} T_{ef} N$$

where E_{co} = emission index at climb-out power, gm per kgm
 M_{co} = fuel flow rate at climb-out power, kgm per sec.

6. Landing and Take-Off Modes (Tables 12q, h, i, and j). Emissions for these modes are expressed in terms of mass of pollutant per unit distance, and are described by the relationship

$$\text{Mass per Unit Distance} = A + BX$$

where A and B are coefficients and X is the distance traveled in the mode in meters. For the landing run, the constant coefficient is given by

$$A, \text{ gm per m} = E_i M_i N / V_b$$

where V_b = velocity at touchdown, m per sec.
 For the take-off run, A is given by

$$A = E_{to} M_{to} \left[2(T_{de}/S_{de}) - 1/V_e \right] N$$

Where T_{de} = time spent in take-off run, sec.

S_{de} = distance of take-off run, m

V_e = velocity at take-off, m per sec.

For the landing run, the first degree coefficient is calculated from the following equation:

$$B, \text{ gm per m}^2 = 2E_i M_i (T_{bc} - S_{bc}/V_b) N/S_{bc}^2$$

where T_{bc} = time spent in landing run, sec

S_{bc} = distance of landing run, m .

For the take-off run, B is given by

$$B, \text{ gm per m}^2 = 2E_{to} M_{to} \left[1/V_e - (T_{de}/S_{de}) \right] N/S_{de}$$

The equations for A and B are obtained from the specifications that this distribution gives both the correct total amount of pollutant emitted during the mode and the correct value for the pollutant per unit distance at touch-down and lift-off.

The total emissions for the landing run are equal to $(E_i M_i T_{bc} N)$, and for the take-off run are equal to $(E_{to} M_{to} T_{de} N)$. The emissions per unit distance at touch-down and take-off are $(E_i M_i N/V_b)$ and $(E_{to} M_{to} N/V_e)$ respectively.

7. Fuel Venting Mode (Table 7). The data in Table 7 give the emission factors for fuel venting in units of grams.

AIRPORT CHARACTERISTICS

Introduction

This section of the report presents the data directly associated with the selected airports which are required for an impact analysis. Since the selected airports originally included four military bases, a small amount of information on these bases is included. However, the predominant part of the information relates to the four air-carrier airports and the two general aviation airports which were selected for complete analysis. The following information is provided for each of these airports:

1. Aircraft activity for time of day, day of week, month and year.
2. Aircraft activity by aircraft class and region of the airport.
3. Aircraft taxi and delay times for each airport.
4. Activity levels for pollutant sources other than aircraft.
5. Meteorological data.
6. Airport plan.

Aircraft Activity by Time Period

Air-Carrier Airports

The object here is to supply adequate information to represent the aircraft activity for any period of the year. For this purpose, the FAA advised that sample days in May and November would provide data on the high and low activity seasons. The attempt has also been made to provide data by hour, day of week, month and year. The data obtained vary according to records kept and the obtainability of these records. Below, the tables which contain this information are presented.

Activity by Hour and Day of Week

Activity by hour and day of week for the air-carrier airports is contained in Tables 13 through 17. The information for these tables has been obtained from References 22 through 25. The values for Los Angeles are given as a percentage of the total daily operations as they are derived

from total values for Los Angeles International, Lockheed Air Terminal and Long Beach. Values from Reference 24 have been adapted to provide a daily variation at LAX, JFK, AND ORD.

Activity by Month and Year

Activity by month and year for the air-carrier airports is contained in Tables 18 through 21. The information for these tables has been obtained from References 22, 23, 26, and 27. In most cases, interpolation of existing data was required to obtain the activity values for 1975 and 1980.

General Aviation and Military Airports

The aircraft activity data obtained for the general aviation and military airports are contained in Tables 22 and 23. They are derived from information in References 9, 28, 29, 30, and 31.

Activity by Aircraft Class and Region of Airports

The information collected in Tables 24 through 31 is directed at two objectives. The values given in Tables 24 and 25 provide information on the relative contribution of each class of aircraft (except for military classes) to the total activity and to the activity for the air-carrier airports under consideration (Refs 32 and 33). The extent of the equivalent information for general aviation airports is given as footnotes in Table 22.

The values in Tables 26 through 31 provide information on the relative activity for each part of the airport. The relative activity levels for the runways have been obtained from flight-path data of References 29 and 34 and from Reference 31 for Tamiami. By associating taxiways with runways, the relative activity by runway has then been used to provide relative taxiway activity. The relative activity by airline provides the necessary data on hangar use and terminal area use where the airline positions are known. In all other cases, activity has been weighted according to approximate size of buildings.

Taxi and Delay Times

Table 32 gives values for taxi and delay times which have been obtained from References 30, 31, 35, and 36. The taxi times include both directions to and from the runway. The delay time applies to the runway.

Heat Generation and Fuel Storage

In Table 33 the fuel, plant rating, and activity are given for the airport heating plant. Table 33 also gives the expected evaporation from the fuel storage tanks.

Automobile Activity

To analyze the emissions from automobile activity within the airport*, the program requires the following items of information:

Average travel per automobile within airport

Automobiles per aircraft passenger seat

Passenger seats per aircraft class.

The available data is not necessarily suited to this categorization (for instance, when automobile activity is given in number per day). It is then necessary to derive from this data the automobiles per aircraft passenger seat. To clarify this procedure, Table 34 gives the required information and also the given information. The values for automobiles per passenger seat are based on values for Los Angeles, Washington National and Tamiami. Numbers of passenger seats have been obtained by taking mean values for each aircraft type and weighting them according to population, except for class 6 where an unweighted mean was taken and class 7 where 1 passenger seat per aircraft was assumed.

Emissions from Airport Surroundings

The lack of satisfactory data for emission indices from airport surroundings has resulted in the following approach to this problem. The

* Emissions from automobile activity on roadways adjacent to an airport do not appear explicitly in the analysis. Rather, they are assumed to be included in the surrounding emissions.

data for St. Louis (Ref 40), which was the most recent data for a city and its surroundings available, has been analyzed to give emission factors for idealized areas such as urban, suburban, park, etc. These values are given in Table 35 for summer, winter, and annual average. The units used are grams per second per square kilometer.

The gross assumption is then made that these emission indices may be applied to the surroundings of each airport. In Figures 1 to 6 the airports and their surroundings are shown in outline, and the subdivisions are classified according to the categories of Table 35. It is thus possible to obtain emission factors for each of the areas surrounding the airports for comparison with the emissions emanating from the airport complex.

Meteorological Data

Meteorological data have been gathered for the four air-carrier airports and the two general aviation airports.* The majority of these data have been obtained from Reference 41. For each airport there are:

1. An array of relative frequencies of all combinations of wind speed class, wind direction sector, and atmospheric stability based on observations at three-hour intervals for 1965 to 1969 inclusive.
2. A complete set of observations at three-hour intervals for 1970.

In addition, values of mixing height for the airports have been obtained from Reference 42. These values are given in Table 36.

Airport Plans

The airport model described elsewhere requires not only relative activity levels between runways, etc., but also the geographical positions of the features which are related to emissions. Therefore, plans of the four air-carrier and two general aviation airports appear in Figures 7 to 12. These show runways, taxiways, hangars, terminal buildings, and position of fuel storage tanks and power plant stacks, where these have been ascertained. The sources for this information are References 22, 23, 30,

* For Van Nuys Airport, meteorological data from Burbank Airport have been used.

31, and 43. It should be noted that the plan for Chicago-O'Hare International Airport does not show runway 4R-22L and the plan for Los Angeles International Airport does not show runway 24R-6L, which are both in use.

MODEL OF AIRPORT EMISSIONS AND ATMOSPHERIC DISPERSION

Introduction

In order to evaluate the impact of pollutant emissions in airport vicinities, a model of airport emissions and atmospheric dispersion of those emissions is required. The results of this modeling effort are presented in detail below. The computer program which is based on the model is presented in Reference 7.

Airport Emissions

The sources of pollutant emissions in the vicinity of a typical airport have been previously discussed. Three categories of emissions were presented: aircraft operations, non-aircraft airport operations, and airport surroundings. In general, each of the sources in these categories can be accurately represented as either point, line, or area sources of time-dependent strength (i.e., emissions per unit time). However, to reduce the complexity of analysis in this study, each emission source is represented by one or more continuous point sources of constant strength over the time period being considered. Each point source is a specific location within the airport or its environs. The strength Q of a point source was evaluated as the total emissions E associated with the point during the time period, divided by the length T of the period. The details of the approach towards modeling emission sources in aircraft operations, non-aircraft airport operations, and airport surroundings follow. The resulting airport models are presented in the section on EMISSION RATES OF THE SELECTED AIRPORTS, including the number and location of emission points.

Aircraft Operations

The modes of operation of a typical aircraft which were considered in this study have been established as: approach, landing, taxi (after landing and before take-off), idle and shutdown, maintenance, start-up and idle, idle at runway, take-off, climb-out, and fuel venting. (As mentioned earlier, fuel venting has been artificially separated from actual operational modes because it is to be considered in a separate task of the study.) The modes are examined in order of complexity of their representation:

1. Idle and Shutdown, Start-Up and Idle. Both of these operational modes have been earlier characterized by a total emission of pollutant per aircraft which is dependent upon aircraft class. The total emissions in these modes for a time period were then calculated using aircraft activity data.

These modes are assumed to be centered about the airport terminals. The emissions are, therefore, divided among point sources located at the terminals, according to a distribution of activity which is characteristic of the airport.

2. Maintenance. Earlier, the maintenance mode had been characterized by a total emission of pollutant per aircraft, which is dependent upon aircraft class. The total emission in the mode for a period of time was calculated using aircraft activity data.

The mode is assumed to take place in the hangar area; therefore, the emissions are divided among point sources located at the hangars, according to a distribution of activity which is characteristic of the airport.

3. Idle at Runway. This operational mode has been earlier characterized by an emission rate of pollutant per aircraft, which is dependent upon aircraft class. The total emissions in this mode for a time period were calculated using aircraft activity data and an idle time which is characteristic of the activity level.

This mode is assumed to take place at the heads of the airport runways. The emissions are, therefore, divided among point sources located at the heads of the runways, according to a distribution of activity which is characteristic of the airport and the prevailing meteorological conditions.

4. Taxi. Since the emission rate and aircraft speed during the taxi mode are very nearly constant, the taxi mode has been characterized by a constant emission rate of pollutant

per aircraft. A distribution of traffic among taxiways and an average taxi time which are characteristic of the airport, allow the total emissions along the taxiway in the time period to be calculated from airport activity data.

The total emissions E_T are distributed among point sources located at stations which divide the taxiway into n equal segments. The emissions of each segment are then divided equally between the two bounding stations. This results in total emissions for the stations at the beginning and end of the taxiway of $E_T/2n$ and for interior stations of E_T/n . This is the same type of distribution as would be obtained for trapezoidal integration of a uniform line source of emissions.

5. Approach, Climb-Out. It is felt that these modes are characterized with sufficient accuracy, as presented earlier, by a total emission of pollutant per aircraft. The distribution of traffic among runways, which is characteristic of the airport and the meteorological conditions, and the airport activity data were used to calculate the total emissions of these modes associated with each runway in the time period.

The total emissions of these modes associated with a runway are distributed along a single approach path and a single climb-out path, respectively. The distribution was accomplished by locating point sources at stations which divide the path into a number of segments. The emissions of each segment, which are assumed to be proportional to the length of the segment, are divided equally between the two bounding stations. The segment lengths were chosen so that they become successively larger as distance from the airport increases.

6. Landing, Take-Off. These modes have been earlier characterized by a linear variation of emissions of pollutant per aircraft per unit distance traveled with distance traveled. The total emissions of these modes associated with each runway

in the time period was then calculated using:

- a. The distance traveled in these modes by an aircraft.
- b. The distribution of traffic among runways.
- c. Aircraft activity data.

Item a is considered to be characteristic of the aircraft class. Item b, on the other hand, is characteristic of the airport and the meteorological conditions.

The total emissions of these modes associated with a runway were distributed among point sources located at stations which divide the runway into a number of equal segments. The emissions of each segment were then divided equally between the two bounding stations. Again, this resulted in the same type of distribution as would be obtained for trapezoidal integration of a linearly varying line source of emissions.

7. Fuel Venting. Fuel venting has been earlier characterized by a total emission of pollutant per aircraft. The distribution of traffic among runways, which is characteristic of the airport and the meteorological conditions, and the airport activity data were used to calculate the total emissions of the fuel venting operation associated with each runway in the time period.

The fuel venting emissions were associated with a point source in the climb-out path at approximately a 600 meter altitude.

Non-Aircraft Airport Operations

The non-aircraft airport operations which are considered in this study as sources of pollution have been established as: ground vehicle travel within the airport, power generation, and fuel storage. The operations were examined in order of complexity of their representation:

1. Heat Generation. This airport operation has been earlier characterized by an emission rate of pollutant per fuel flow rate. The total emissions of an airport heating plant

for a time period were calculated using the average fuel flow rate of the heating plant, the length of the time period, and the plant activity level during the time period.

The emissions of each heating plant are associated with a point source located at the heating plant.

2. Fuel Storage. Fuel storage emissions have been earlier characterized by an emission rate of pollutant per fuel storage area. The total emissions due to fuel storage for a time period were calculated using the length of the time period, and summing the contributions of each fuel storage area.

The emissions from each fuel storage area are associated with a point source located in the fuel storage area.

3. Automobile Travel. Automobile travel within the airport* has been earlier characterized by a constant emission of pollutant per automobile per unit automobile travel. The total emissions due to automobile operation for a time period were calculated using:
 - a. Average travel per automobile within the airport.
 - b. Fraction of automobiles entering the airport per passenger.
 - c. Average number of passengers per aircraft.
 - d. Aircraft activity data.

The first two items are considered characteristic of the airport, while the third item is considered characteristic of an aircraft class.

The total emissions were distributed along the airport roadway system, which in addition to highways, included roads within the parking areas. The distribution is accomplished by locating point sources at stations which divide each roadway into a number of equal segments. The emissions

* Again, automobile travel on roadways adjacent to the airport are not explicitly considered.

of each segment were equally divided between the two bounding stations. Again, this resulted in the same type of distribution as would be obtained for trapezoidal integration of a uniform line source of emissions.

Service vehicle emissions were calculated in an approximate manner, using data in Reference 37, as 50 per cent of automobile emissions. They are then included in the distribution of the automobile emissions.

Airport Surroundings

The airport surroundings have been characterized by a constant emission rate of pollutant per unit area of surroundings, the constant being dependent upon the category of the surroundings. The total emissions due to the surroundings for a time period were calculated using the area and category of each segment into which the surroundings are divided, the length of the time period, and the average activity level in the time period.

The total emissions of each area segment of the surroundings are associated with a point source located at the segment.

Atmospheric Dispersion

Since each emission source in the vicinity of an airport has been represented by one or more continuous point sources, the discussion of atmospheric dispersion which follows is primarily concerned with such sources.

Background

The dispersion of pollutants by the atmosphere occurs through four mechanisms: transport, diffusion, transformation, and loss. In this context, transport refers to mass transfer resulting from the mean motion of the wind, while diffusion refers to mass transfer resulting from turbulent mixing in the atmosphere. (It should be noted that diffusion due to turbulent mixing is a more important effect than molecular gas diffusion by several orders of magnitude.) Transformation refers to a change of composition due to

physical, chemical, or photochemical reactions. Finally, loss mechanisms refers to the precipitation of pollutants from the atmosphere due to the presence of rain, snow, or ice, or simply due to their own weight, as well as retention of pollutants by the ground through impaction or absorption.

The modern analytical treatment of the dispersion mechanisms of transport and diffusion originates with the Fickian form of the diffusion equation:

$$\frac{dx}{dt} = K_x \frac{\partial^2 x}{\partial x^2} + K_y \frac{\partial^2 x}{\partial y^2} + K_z \frac{\partial^2 x}{\partial z^2}$$

where x is the concentration of any specie of interest at any point x, y, z , and K_x, K_y , and K_z are the coefficients of anisotropic diffusion. A rigorous treatment of the development of solutions to the diffusion equation was presented by Sutton (Ref 44) in 1953. Solutions are given for sources in an atmosphere at rest or in a wind. In particular, an approximate solution for a steady-state continuous point source Q in a wind u , is given as:

$$x(x, y, z) = \frac{Q}{4\pi x (K_y K_z)^{1/2}} \exp \left[-\frac{u}{4x} \left(\frac{y^2}{K_y} + \frac{z^2}{K_z} \right) \right]$$

where x represents the downwind direction. The form of this solution did not prove to be very convenient, and an empirical double-Gaussian plume form was adopted by Pasquill (Ref 45) and Gifford (Ref 46). This formulation, which is the basis for most current model calculations, is expressed as:

$$x(x, y, z; H) = \frac{Q}{2\pi \sigma_y \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right] \cdot \left\{ \exp \left[-\frac{1}{2} \left(\frac{z-H}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{z+H}{\sigma_z} \right)^2 \right] \right\}$$

where y represents the crosswind direction, z represents the vertical direction, H is the effective height of the source (reflecting buoyancy of the plume), and σ_y and σ_z are crosswind and vertical measures, respectively, of plume spread which are dependent upon downwind distance and atmospheric stability. It should be noted that this formulation does represent a valid solution to the Fickian diffusion equation. Further,

it satisfies conservation of mass; loss of pollutant to the ground was not modeled.

The remaining dispersion mechanisms of transformation and deposition have not been successfully included in a dispersion model, except on a very simple level. This simplified treatment modifies the concentrations due to transport and diffusion by an exponential decay term of the form

$$\exp \left[-\frac{1}{k} \frac{x}{u} \right]$$

where k is the time constant for the system.

Long-Term Average Dispersion Model

The model of atmospheric dispersion which was used to compute long-term average concentrations in the vicinity of an airport, is based on the work of Martin (Ref 47). It is known as the Martin-Tikvart model and is based on a variation of the double-Gaussian equation above.

In its generalized form, the Martin-Tikvart model states that the long-term average concentration $\bar{x}$ at a receptor point x, y, z is given by:

$$\bar{x} = \sum_{n=1}^N \sum_{l=1}^L \sum_{s=1}^S F(D_n, l, s) \cdot x$$

where n is the source index, l is the stability class of atmosphere,

s is the wind-speed class, D_n is the $22\frac{1}{2}$ degree wind-direction sector* in which transport from source n to the receptor point occurs, F is the relative frequency of winds in the sector D_n for wind-speed class s and stability class l , and x is the concentration at a point in the sector D_n for a particular combination of meteorological conditions due to a point source.

If M is the height of the upper limit to vertical mixing, and p is the horizontal distance between receptor and source, then unrestricted vertical diffusion of the pollutant is assumed for values of p less than p_M where p_M is defined by:

$$\sigma_z(p_M, l) = 0.47 M$$

* Wind direction is assumed to be specified to a 16-point compass, corresponding to $22\frac{1}{2}$ degree sectors. All wind directions within a particular sector are assumed to occur with equal probability.

In this case, the concentration χ at a point in sector D_h is given by:

$$\chi = \frac{Q}{\sqrt{2\pi} \sigma_z u (2\pi \rho / 16)} \left\{ \exp \left[-\frac{1}{2} \left(\frac{z-H}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{z+H}{\sigma_z} \right)^2 \right] \right\} \cdot \exp \left[-\frac{1}{k} \frac{\rho}{u} \right]$$

It can be seen that this equation is not applicable for the case when $\rho=0$. During the computation, the contribution to the concentration at a receptor point in such a situation will be set equal to zero.

If ρ is greater than $2\rho_m$, it is assumed that the trapping effect of the upper limit to vertical mixing has resulted in a uniform vertical distribution of concentration. The concentration χ in sector D_h is given by:

$$\chi = \frac{Q}{Mu (2\pi \rho / 16)} \cdot \exp \left[-\frac{1}{k} \frac{\rho}{u} \right]$$

Finally, if the value of ρ lies between ρ_m and $2\rho_m$, the concentration will be approximated by linear interpolation between the concentrations at ρ_m and $2\rho_m$.

Short-Term Maxima Dispersion Model

The calculation of short-term maxima concentrations requires a much narrower range of meteorological conditions to be examined than the distribution considered above. In fact, the time period for such calculations has been divided into periods which are characterized by single values of wind-speed class and atmospheric-stability class, by a mean wind direction, and by a wind persistence as measured by the angular variation of the wind direction during the time period. The combination of meteorological conditions was chosen from observations of hourly meteorological data to represent the maximum potential for pollutant concentrations.

Whereas the approximation involving crosswind direction in the Martin plume equation tends to cancel itself when there is a distribution of meteorological conditions, this could not be assumed here. Hence, the short-term model was based on the double-Gaussian plume equation, where the wind direction is uniformly distributed over the specified range. In

its generalized form, the model states that the short-term maxima concentration χ_{MAX} at a receptor point X, y, z is given by:

$$\chi_{MAX} = \frac{1}{D} \sum_{n=1}^N \sum_{d=1}^P \chi_{n,d}$$

where d is the wind-direction index, D is the number of equally spaced wind directions which represent the range of wind directions, n is the source index, and χ is the concentration due to a point source for the specified meteorological conditions.

If M is the height of the upper limit to vertical mixing and X' is the downwind distance from the source to the receptor, then unrestricted vertical diffusion can be assumed for values of X' less than X'_M where:

$$\sigma_z(x'_M, l) = 0.47 M$$

In this case the concentration χ is given by:

$$\chi = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y'}{\sigma_y}\right)^2\right] \cdot \left\{ \exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] \right\} \cdot \exp\left[-\frac{1}{k} \frac{x}{u}\right]$$

where y' is the crosswind distance from the source to the receptor.

For values of X' greater than $2X'_M$, the concentration is given by:

$$\chi = \frac{Q}{\sqrt{2\pi}\sigma_y M_u} \exp\left[-\frac{1}{2}\left(\frac{y'}{\sigma_y}\right)^2\right] \cdot \exp\left[-\frac{1}{k} \frac{x}{u}\right]$$

Again, for values of X' which lie between X'_M and $2X'_M$, the concentration is approximated by linear interpolation between the concentrations at X'_M and $2X'_M$.

Meteorological and Diffusion Parameters

The meteorological and diffusion parameters which appear in the dispersion model are: wind speed, wind direction and its persistence, stability of the atmosphere, mixing height of the atmosphere, parameters

of vertical and horizontal plume spread, plume rise, and time constant of exponential decay.

Wind speeds are grouped into six classes: 0-3, 4-7, 8-12, 13-18, 19-24, and greater than 24 mph. The value of U which appears in the concentration equations is taken to be one of the midpoint values of the speed classes. This avoids the singularity of the concentration equations under calm conditions.

The wind direction in the long-term dispersion model was classified into the sixteen sectors of the compass: N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW. In the short-term dispersion model, on the other hand, the wind direction was classified by a range of values whose included angle is a measure of the persistence of the wind direction.

The stability of the atmosphere was divided, following Martin (Ref 47), into six classes for rural areas and five classes for urban areas. (The stability class number increases in order of increasing stability.) The reduction in number of stability classes for urban areas was achieved by combining the two most stable classes. Hence, the wind-stability frequency distributions prepared by the National Climatic Center, which is based on the six stability classes, could still be used to calculate long-term average concentrations.

Mixing height of the atmosphere is a parameter which can vary greatly from morning to night, from day to day, and from season to season. In the calculation of long-term average concentrations, mixing height was treated again as recommended by Martin (Ref 47). Mean annual afternoon mixing heights, as tabulated by Holzworth (Ref 42) for locations throughout the United States, are modified according to stability class of the atmosphere and whether the area is rural or urban. If the stability class is 1, the Holzworth value is increased by 50 per cent. If the stability class is 5 and the area is urban, the mixing height is assumed to be 100 meters. If the stability class is 4, 60 per cent of the emissions were assumed to take place using the Holzworth mixing height and 40 per cent were assumed to take place with a lower mixing height. The lower height was taken to be 50 per cent of the Holzworth value if the area is rural, or 50 per cent of the sum of the Holzworth value and 100 meters if the area

is urban. In the calculation of short-term maxima concentrations, mixing heights tabulated by Holzworth which are representative of the time period were used.

Values of the parameters of vertical and horizontal plume spread, σ_z and σ_y , respectively, are based on the data presented in graphical form by Turner (Ref 48). The graphs, showing the variation of the parameters with downwind distance for each stability class are reproduced in Figures 13 and 14.

The various correlations in the literature, as surveyed by Briggs (Ref 49), for example, indicate that plume rise is dependent upon buoyancy and vertical velocity of injection of the plume. Since buoyancy is quickly dissipated, this would indicate a small plume rise for aircraft sources. There is no experimental data which shows that this is not substantially the case. Hence, zero plume rise was assumed for all emission sources in the study; this being a conservative assumption, leading to larger values of concentration.

The time constant of exponential decay is a parameter which varies from pollutant to pollutant. However, considering typical distances and wind speeds involved, it is felt that an infinite time constant can be assumed in all cases. Again, this is a conservative assumption, leading to larger values of concentration. If, for future cases, there is evidence that a finite value of the time constant should be used for any pollutant, the mechanism will be available.

SENSITIVITY AND ACCURACY OF THE MODEL

Introduction

An important part of the development of the computer program for air quality analysis, was an investigation of the sensitivity and accuracy of the model of airport emissions and atmospheric dispersion. The results of that effort are presented below.

Model Sensitivity

The mathematical model of airport emissions and the dispersion of those emissions used to predict pollutant concentrations involves two categories of physical parameters:

1. Meteorological parameters which consist of atmospheric stability, wind speed, wind direction, mixing height, and, for short-term calculations, wind persistence.
2. Source parameters which consist of the strength and location of emission sources with respect to a receptor.

Parameters in the first category were the subject of a sensitivity analysis. On the other hand, parameters in the second category were investigated indirectly in the analysis of control techniques, as described in a later section of the report.

The sensitivity analysis of the meteorological parameters was conducted using Los Angeles International Airport as the site. Concentrations of carbon monoxide were calculated for an eight-hour averaging period. The datum meteorological conditions of the analysis were:

Wind speed class = 2 (4-7 mph)
Atmospheric stability class = 3 (slightly unstable)
Wind direction = West
Wind persistence = 45 deg
Mixing height = 933 m

These values correspond to a fairly average day-time set of conditions. Receptor points were equally divided between positions within the airport,

on the airport boundaries, and in the surroundings; a total of 24 receptor points were used. Sensitivity was measured by the arithmetic average of all the calculated concentrations, known as the average value, and by the arithmetic average of the highest three values, known as the maximum value. For each parameter, a higher and lower value of the parameter was considered. The resulting changes of the concentrations were then evaluated as a percentage of the datum values.

The results of the sensitivity analysis for the meteorological parameters are shown in Table 37. It can be seen that the concentrations are most sensitive to a change in wind speed class. This is due to the fact that concentration is inversely proportional to wind speed and the wind speed changes considerably between classes. The concentrations are also quite sensitive to changes in wind persistence and atmospheric stability. Greater wind persistence (a smaller included angle) is seen to result in higher concentrations. Greater stability of the atmosphere (higher stability class) is also seen to result in higher concentrations. In the case of wind direction, it is seen that concentrations decrease if the direction is changed from the west. This is due to the fact that the runways are oriented in the east-west direction (the prevailing winds at LAX are from the west). Finally, it is seen that mixing height, within the range considered, has no effect on the concentrations. This result is obtained because of the scale of the airport and its surroundings as compared to the datum mixing height. However, much smaller values of the mixing height would result in significant changes in the concentrations.

The results of the sensitivity analysis for the meteorological parameters have a direct bearing on the selection of short-term periods used to calculate maxima concentrations in the impact analysis. Hence, time periods which exhibit low wind speeds, stable atmospheric conditions, and high wind persistence in the prevailing direction should be selected.

Accuracy of the Model

The modeling of airport emissions is accomplished by a large number of continuous point sources of constant strength distributed

throughout the airport. This results in two limitations to the validity of the model. Firstly, the model is limited to time periods which are much larger than characteristic times of individual aircraft activity. This is required by the assumption of continuous sources. Since predicted concentrations are not required for time periods less than an hour in length and the characteristic times of individual aircraft activity are a few minutes at the most, this is not an important limitation. Secondly, the model is limited to receptors which are not in close proximity to the emission sources. This is required by the assumption of point sources. The representation of a line or area source by one or a number of point sources will result in inaccuracies which increase with proximity to the source. The magnitude of the inaccuracy for a specified distance between receptor and source point will depend on the physical dimensions of the actual source. Since an airport has many emission sources which would be best represented as lines or areas, the assumption of point sources results in an important limitation of the model. In order to limit the magnitude of a predicted concentration due to a point source, receptor locations within 100 meters of the point are not considered valid in this study. The distance of 100 meters is suggested by the lack of plume spread data below that value (see Figures 13 and 14).

The modeling of atmospheric dispersion is also known to have inherent inaccuracies due to the complexity of simulating weather and dispersion conditions. Other sources of inaccuracy are the aircraft emission factors and the distribution of activity within the airport.

To provide a check of the results obtained using the model, a comparison was made with emissions and concentrations reported in Reference 11 for Los Angeles International Airport. Table 38 gives a comparison of total aircraft emissions for the year 1970. It can be seen that, while the emissions for carbon monoxide are in excellent agreement, agreement for the other pollutants is poor. The aircraft emissions of particulates, nitrogen dioxide, total hydrocarbons, and sulfur dioxide from Reference 11 are greater than those obtained using the model by factors ranging from 2.4 for sulfur dioxide to 6.7 for particulates. Since the activity data was quite similar for the two cases, the disagreement can be traced directly to the emission factors. For sulfur dioxide, it is due to the amount of

sulfur assumed to be in jet fuel, which in Reference 11 was a factor of 2.4 greater than the value assumed in this report. The amount of sulfur actually in jet fuel varies greatly (by as much as a factor of 20), depending on where the oil originates and the refining procedure. Concerning the other pollutants, it is significant that agreement is so good for carbon monoxide which can be measured most accurately in engine emission tests and bad for the other pollutants where different measurement techniques can give very different results. The greatest difference would be expected for particulates where measurement differences are compounded by disagreement as to the definition of particulates. The definition used by the Air Pollution Control District, County of Los Angeles, includes wet particulates in addition to the dry particulates considered in this report.

Table 39 gives a comparison of total airport emissions for the year 1970 at LAX. The same general pattern of agreement is found as above, but the differences are in general smaller.

Atmospheric measurements of carbon monoxide and particulates at LAX are also reported in Reference 11. For the six month period from May through October, 1970, the average measured concentrations of carbon monoxide and particulates outdoors in the terminal area were found to be 6.9 mg/m^3 and $140 \text{ } \mu\text{g/m}^3$, respectively. The comparable values obtained analytically, using the model of airport emissions and atmospheric dispersion previously described, were calculated to be 2.5 mg/m^3 and $24 \text{ } \mu\text{g/m}^3$.

The measured concentration of carbon monoxide is a factor of 2.8 larger than the analytical value. Since the carbon monoxide emissions for the airport used to predict the concentration agree very closely with the value in Reference 11, the difference in the concentration would seem to be due to either inaccurate dispersion modeling of the airport emissions or inaccurate modeling of the surroundings. It is felt that the crude manner used to model the surroundings is the more likely cause*. Hence, concentrations due to aircraft emissions alone, should be predicted more accurately than concentrations due to all emissions.

* For instance, emissions of automobiles on roadways adjacent to the airport were not directly included in the model.

In the case of particulates, the measured concentration is a factor of 5.8 larger than the analytical value. This would seem to be due mainly to the factor of 6.6 by which the total airport emissions of particulates given in Reference 11 exceeds the value used to predict the concentration.

EMISSION RATES OF THE SELECTED AIRPORTS

Introduction

This section of the report is concerned with the emission rates which have been calculated at each of the selected airports. The following information is presented and discussed:

1. Annual emissions for the year 1970 at each of the selected airports.
2. Areal distribution of emission rates at Washington National Airport.
3. Time-period variations of emissions at Washington National Airport.
4. Aircraft emissions by mode of operation for 1970 at Washington National Airport.

Included in the presentation of the first item is a model of each airport used throughout the calculations.

Annual Emissions for 1970

The model of Washington National Airport used throughout the calculations is shown in Figure 15. This figure has the same scale as the plan of Washington National Airport given in Figure 8 to facilitate ready identification of the positions of all airport features. All airport runways are included in the model; however, only three taxiways and two roadways are considered necessary. Other airport features, such as terminals, hangars, fuel storage areas, and a heating plant, are also approximated in the model.

Annual emissions of Washington National Airport and its surroundings are presented in Table 40. The results are based on 1970 aircraft activity data and the emission factors presented earlier in the report. For each pollutant, the emissions are grouped according to their sources into three categories: aircraft emissions, non-aircraft airport emissions, and airport surroundings emissions. The aircraft emissions are further subdivided into those from ground operations and those from

flight operations. Non-aircraft airport emissions are further subdivided into automobile emissions and another group made up of heating plants and fuel storage area emissions.

An examination of the tabulated emissions reveals the following salient features:

1. Approximately 55 per cent of the total CO generated within the airport comes from aircraft sources. Emissions from ground operations far outweigh contributions from flight operations.
2. Approximately 60 per cent of the total emissions of nitrogen oxides generated by airport sources comes from aircraft. Emissions from automobiles and the heating plant (which uses fuel oil) are substantial. The aircraft emissions are primarily generated during flight operations.
3. The high sulfur content of the fuel oil used in the heating plant is reflected in the dominant contribution of this source to the sulfur dioxide emissions.
4. Total particulates are chiefly generated by aircraft sources. Ground operations are responsible for about 15 per cent of total aircraft contributions.
5. Lead emissions are chiefly generated by automobiles. Aircraft sources contribute about 10 per cent of the total airport emissions of lead.
6. About 65 per cent of total hydrocarbon emissions are generated by aircraft sources; the other 35 per cent are generated by automobiles. Ground operations account for approximately 55 per cent of the aircraft emissions.
7. Total emissions from the surroundings are generally much higher than the emissions within the airport (with the exception of lead, for which no emission data is available). This is due to the large areas of surroundings specified in the calculations - areas within a 10 km radius from the center of the airport are used.

J. F. Kennedy International Airport

The model of J. F. Kennedy International Airport used throughout the calculations is shown in Figure 16. Four runways and ten terminals are served by the nine taxiways. The roadway system within the airport is represented by eight linear segments.

Table 41 presents the annual emissions at J. F. Kennedy International Airport for 1970. The general trend of the relative contributions from the various emission categories for each pollutant is similar to that of Washington National Airport. An exception is total hydrocarbon emissions where ground operations account for about 85 per cent of the aircraft contribution. Total emissions at JFK are much higher, however, reflecting the higher level of activity at this airport. Emissions from the surrounding areas are much lower than corresponding contributions at DCA. This is due to a smaller surrounding area within the 10 km circle and the presence of large water masses in that area.

Los Angeles International Airport

The model of Los Angeles International Airport used throughout the calculations is shown in Figure 17. Four parallel runways are served by twelve taxiways. Three roadways are needed to model the access of the terminals from major automobile arteries. Another roadway gives access to the hangars and fuel storage areas.

Annual emissions by pollutant at Los Angeles International Airport for 1970 are given in Table 42. The magnitude of the emissions and the general trend of the component contributions are similar to that of JFK.

Chicago-O'Hare International Airport

The model of Chicago-O'Hare International Airport used throughout the calculations is shown in Figure 18. Six runways are served by seven taxiways. The five terminals are served by a roadway system made up of five linear segments.

O'Hare is the busiest airport in the study group, and this is reflected in the magnitude of the annual emissions for 1970 as shown in Table 43. Relative contributions from the various categories again show the same trend as with the other air-carrier airports. Emissions from the surrounding areas are comparable to that of DCA.

Van Nuys Airport

The model of Van Nuys Airport used throughout the calculations is shown in Figure 19. This busy general aviation airport has two parallel runways. Three taxiways and four roadways provide aircraft and automobile access. Due to a lack of more complete information, hangars, and fuel storage areas are distributed among six terminal areas. Annual emissions of the Van Nuys Airport for 1970 are presented in Table 44. Due to differences in emission factors of the various aircraft classes and in composition of the aircraft population at this airport, the component contributions from the various categories exhibit a different trend in comparison with that of the air-carrier airports. Examination of Table 44 reveals the following differences:

1. Emissions from ground operations exceed those from flight operations for nitrogen oxides and particulates.
2. Automobile emissions exceed those from aircraft for nitrogen oxides and sulfur dioxide, while the opposite is true for lead.

New Tamiami Airport

The model of New Tamiami Airport used throughout the calculations is shown in Figure 20. Three runways are serviced by seven taxiways. Fuel storage areas and hangars are located at the terminals. Four roadways give access to the terminals. Annual emissions of New Tamiami Airport for 1970 are presented in Table 45. Aircraft emissions at Tamiami are somewhat smaller than those of Van Nuys, but they form a larger percentage of the total airport emissions. Otherwise, the relative contributions of the various emission categories are similar to those of Van Nuys.

Areal Distribution of Emission Rates At Washington National Airport

The areal distribution of rates at Washington National Airport is given in Table 46. It consists of the x- and y-coordinates of each point source with respect to the chosen center of the airport, together with the pollutant emission rates of the point. The distribution is considered to be representative of those which have been obtained for the other selected airports.

Along each runway, the specified number of ground source points, climb-out source points, and approach source points are 10, 5, and 5, respectively. Hence, with a total of five runways, the total number of sources along runways is 100. Five source points equally spaced along each of the three taxiways account for the 15 points along the taxiways. Similarly, five source points are specified for each of the two roadways. For each of the surrounding areas, the associated source point is located at the geometric center of the area. Terminals, hangars, heating plants, and fuel storage areas are all single-point sources.

Time-Period Variations of Total Emissions at Washington National Airport

Variations of total emissions with time period result primarily from changes in the level of aircraft activity. Emissions at Washington National Airport were obtained for the following periods:

1. Peak month, i.e., the month with the highest level of activity.
2. Low month.
3. Peak day.
4. Low day.
5. Morning hour.
6. Noon hour.
7. Evening hour.

Although DCA does not exhibit the variation of activity level of some of the other airports, it was used as an example in this case because of the detail of its activity data.

Monthly Variation of Emissions

June is observed to be the month of peak activity at DCA, while

February is the month of lowest activity. The total emissions at DCA for the months of June and February are given in Tables 47 and 48, respectively. The emissions of the various pollutants in February are seen to be approximately 80 per cent of the corresponding values in June. The activity variation between the two months shows the same percentage change.

Daily Variation of Emissions

In general, Friday exhibits the highest level of activity for a day of the week, while Saturday has lowest activity. The total emissions at DCA for a Friday and a Saturday in February are given in Tables 49 and 50, respectively. The emissions of the various pollutants for Saturday are seen to be approximately 70 per cent of the corresponding values for Friday. Again, this is about the same percentage change shown by the activity variation between the two days.

Hourly Variation of Emissions

Variations in total emissions with the time of day were investigated by considering a morning hour (8 am to 9 am), the noon hour (12 am to 1 pm), and an evening hour (6 pm to 7 pm). The morning and evening hours represent high levels of activity for the respective periods, while the noon hour corresponds to a lull in the daily activity. The total emissions at DCA for these three one-hour periods are given in Tables 51, 52, and 53, respectively. The emissions of the various pollutants for the noon hour are seen to be approximately 80 per cent of the corresponding values for the morning hour. The emissions for the evening hour are approximately 90 per cent of the values for the morning hour.

Aircraft Emissions by Mode

The total emissions by pollutant associated with each mode of aircraft operations and with the complete operational cycle at Washington National Airport for 1970, are given in Table 54. Salient features of these emissions are discussed below.

Approach

Carbon monoxide, particulate, and total hydrocarbon emissions are the main pollutants emitted in this mode. Nitrogen oxide, sulfur dioxide, aldehyde, and total particulate emissions from this mode contribute substantially to the total from all aircraft operations. Emissions of this mode occur at altitude and are distributed over relatively large distances from the airport.

Landing

In terms of total emissions from the complete operational cycle, emissions from the landing mode are generally small. This mode is confined to the runways.

Taxi

Judged in terms of percentage contributions to total aircraft emissions, the taxi mode is by far the most culpable for most of the pollutants studied. The following figures substantiate the charges: carbon monoxide - 50 per cent, nitrogen oxide - 6 per cent, sulfur dioxide - 14 per cent, particulates - 6 per cent, lead - 35 per cent, total hydrocarbons - 33 per cent, and aldehydes - 19 per cent.

Idle and Shutdown

The idle and shutdown mode takes place at the terminal locations. Emissions from this mode are comparable to that of the landing mode, and are therefore relatively insignificant.

Maintenance

Emissions during maintenance at the hangars are generally high - comparable to the approach mode.

Start-up and Idle

In contrast to the shutdown mode, emissions from start-up and idle are quite significant. In almost all pollutant species considered,

the emissions from this mode exceed that of the shutdown mode by a factor of four or more.

Idle at Runway

Emissions from this mode are of the same order of magnitude as from the maintenance mode in all pollutants studied. Its carbon monoxide and hydrocarbon emissions exceed that from the approach mode.

Take-Off

With the exception of carbon monoxide emissions, the take-off mode results in high emissions of the various pollutant species. Emissions from take-off are about one order of magnitude higher than corresponding emissions from the landing mode.

Climb-Out

Nitrogen oxide emissions from this mode are very high; about 45 per cent of all aircraft nitrogen oxide emissions come from this mode. The same is true for sulfur dioxide emissions, 35 per cent, total particulates emissions, 37 per cent, lead emissions, 25 per cent, and aldehyde emissions, 25 per cent. The impact upon the airport from these high emissions is reduced, however, due to the fact that these emissions are at altitude and are distributed over large distances from the airport.

Fuel Venting

Only total hydrocarbons are associated with emissions from this mode. The amount of pollutant involved is substantial, accounting for some 33 per cent of total hydrocarbon emissions from the entire operational cycle. This value, however, is not typical of the other air-carrier airports, where fuel venting only accounts for about 6 per cent of the total hydrocarbon emissions.

IMPACT ANALYSIS OF THE SELECTED AIRPORTS

Introduction

This section consists of a discussion of the impact of aircraft emissions on air quality at the selected airports and their immediate vicinities. The following information is presented:

1. Locations of receptor points at which concentrations are calculated.
2. Predicted annual average concentrations of particulates, nitrogen dioxide, sulfur dioxide, and lead.
3. Predicted short-term maxima concentrations of the specified pollutants and their associated time periods:
 - a. Carbon monoxide, 8-hour and 1-hour.
 - b. Sulfur dioxide, 24-hour and 3-hour.
 - c. Particulates, 24-hour.
 - d. Nitrogen dioxide, 24-hour.
 - e. Total hydrocarbons, 6 am - 9 am.

It should be noted that a lack of local meteorological observations prevented the short-term concentrations from being calculated at Van Nuys Airport.

The predicted concentrations, except for lead and 24-hour nitrogen dioxide values, were compared to the national primary and secondary ambient air quality standards (Ref 50). The primary standards are those which, in the judgement of the Administrator of the Environmental Protection Agency, are requisite to protect the public health. The secondary standards are those which, in the judgement of the Administrator, are requisite to protect the public welfare. These primary and secondary standards appear in Table 55. It can be seen that the hydrocarbon standard is for non-methane hydrocarbons. The predicted concentrations of total hydrocarbons must, therefore, be reduced by 10 per cent to account for the methane content when compared to the hydrocarbon standard. This percentage is an approximate figure and a somewhat higher value might also be assumed. It should also be recognized that the hydrocarbon standard is a guide to achieving the oxidant standard.

The predicted lead concentrations were compared to $2-3 \mu\text{g}/\text{cu m}$ which is the range of airborne lead concentrations associated with increases in blood-lead levels (Ref 51). The predicted 24-hour concentrations of

nitrogen dioxide were to have been compared with a proposed standard, which has since been eliminated.

Receptor Postions at Selected Airports

The over-all scheme which was used to select the receptor points at each airport is as follows:

1. One receptor at the center of each major terminal.
2. One receptor at 100 meters from the head of each runway.
3. Two receptors at 20 meters and 50 meters, respectively, from the head of the busiest runway.*
4. Sixteen receptors on the airport boundary, spaced equally on a compass rose located at the chosen center of the airport.
5. Another sixteen receptors located in the airport surroundings, 5 km from the center of the airport and spaced equally on the compass rose.
6. For short-term calculations, mobile receptors located 100 meters directly downwind of the two busiest runways.

Variation in the total number of terminals and runways from one airport to the next results in changes in the over-all distribution outlined above.

Figures 21 and 22 show 42 of the 46 permanent receptors located at Washington National Airport. Not shown on the figures are receptors 20, 21, 29, 30, 47, and 48. Receptors 20 and 21 are located on the airport boundary in the SSE and S directions, respectively, from the center of the airport. Receptor 29 is 1 km in the W direction from the center of the airport, adjacent to the George Washington Memorial Parkway, while receptor 30 is located at the Pentagon. Receptors 47 and 48 are the mobile receptors, which are adjacent to receptors 6 and 10, respectively, for all short-term periods except 6 am to 9 am where they are adjacent to receptors 5 and 9, respectively. It should also be pointed out that receptors 11 and 12 are 50 m and 20 m, respectively, from the head of runway 18-36.

Figures 23 and 24 show 49 of the 50 permanent receptors located at J. F. Kennedy International Airport. Not shown on the figures is receptor 32. Receptor 32 is located on the airport boundary in the WNW

* Concentrations calculated at these receptors are not considered reliable due to the proximity of source and receptor.

direction from the center of the airport. Receptors 16 and 18 double as the mobile receptors in the short-term calculations.

Figures 25 and 26 show 46 of the 48 permanent receptors located at Los Angeles International Airport. Not shown on the figures are receptors 31, 32, 49, and 50. Receptors 31 and 32 are located at 50 m and 20 m, respectively, from the east end of runway 7L-25R, adjacent to receptor 12. Receptors 49 and 50 are the mobile receptors, which are adjacent to receptors 9 and 11, respectively.

Figures 27 and 28 show the 49 permanent receptors located at Chicago-O'Hare International Airport. Receptors 8 and 9 are actually located at the ends of runway 4R-22L, which is not shown in Figure 7. Receptors 24 through 28 are located on the airport boundary in the SE, SSE, S, SSW, and SW directions, respectively, from the center of the airport. Receptors 7, 9, 11, and 13 double as the mobile receptors in the short-term calculations.

Figures 29 and 30 show 30 of the 32 permanent receptors located at Van Nuys Airport. Not shown on the figures are receptors 14 and 15. Receptors 14 and 15 are located on the airport boundary in the NW and NNW directions, respectively, from the center of the airport.

Figures 31 and 32 show the 46 permanent receptors located at New Tamiami Airport. Not shown on the figures are receptors 47 and 48. Receptors 47 and 48 are the mobile receptors, which are adjacent to receptors 10 and 12, respectively, for all short-term periods except the 24 hour period where they are adjacent to receptors 9 and 11, respectively.

Annual Average Concentrations

At any given receptor point, the total concentration is obtained by summing the contributions from all emission sources. In the annual average calculations, characteristic stability wind-rose data for each airport is used to weigh the individual contributions. The total concentration, by pollutant, at a receptor point is broken down into three major source categories: aircraft, non-aircraft airport, and surroundings. Typical concentration output for a receptor is exemplified by receptor 1 at Washington National Airport, as shown

in Table 56. The array of annual average concentrations for each selected airport is discussed below.

Washington National Airport

Annual average concentrations for particulates, nitrogen dioxide, sulfur dioxide, and lead at Washington National Airport are contained in Table 57. It can be seen that the air quality standards for nitrogen dioxide and sulfur dioxide are exceeded at a number of receptors.

For nitrogen dioxide, the primary and secondary standard is exceeded at eight receptor locations. The locations are categorized below with the percentage contribution from aircraft sources:

- Two terminal locations - 10 per cent aircraft
- One runway location - 60 per cent aircraft
- Four boundary locations - 7 per cent aircraft
- One surrounding location - 2 per cent aircraft

For sulfur dioxide, the primary standard is exceeded at three receptor locations on the airport boundary with 2 per cent aircraft contributions. The secondary standard is exceeded at five additional receptors:

- One terminal location - 7 per cent aircraft
- One boundary location - 7 per cent aircraft
- Three surrounding locations - 1 per cent aircraft

J. F. Kennedy International Airport

Annual average concentrations for particulates, nitrogen dioxide, sulfur dioxide, and lead at J. F. Kennedy International Airport are contained in Table 58. It can be seen that the air quality standards for nitrogen dioxide and sulfur dioxide are again exceeded at a number of receptors. Also, the potentially harmful level of lead is exceeded at a number of receptors.

For nitrogen dioxide, the primary and secondary standard is exceeded at twelve receptor locations. The locations are categorized below with the percentage contribution from aircraft sources:

- Nine terminal locations - 5 per cent aircraft
- One roadway location - 7 per cent aircraft
- Two runway locations - 12 per cent aircraft

For sulfur dioxide, the secondary standard is exceeded at one receptor location - a terminal location with 7 per cent aircraft contributions.

For lead, the potentially harmful level is exceeded at locations which have negligible aircraft contributions.

Los Angeles International Airport

Annual average concentrations for particulates, nitrogen dioxide, sulfur dioxide, and lead at Los Angeles International Airport are contained in Table 59. It can be seen that the air quality standards are exceeded for the first three pollutants, while the potentially harmful level is exceeded for lead.

For particulates, the primary and secondary standards are both exceeded at three receptor locations. The locations are at the heads of runways and have a 90 per cent aircraft contribution.

For nitrogen dioxide, the primary and secondary standard is exceeded at thirteen receptor locations. The locations are categorized below with the percentage contribution from aircraft sources:

Six terminal locations - 13 per cent aircraft

Five runway locations - 65 per cent aircraft

Two boundary locations - 8 per cent aircraft

For sulfur dioxide, the primary standard is exceeded at one receptor location - a runway location with 90 per cent aircraft contributions. The secondary standard is exceeded at two additional receptors - runway locations with 90 per cent aircraft contributions.

For lead, the potentially harmful level is exceeded at locations which have negligible aircraft contributions.

Chicago-O'Hare International Airport

Annual average concentrations for particulates, nitrogen dioxide, sulfur dioxide, and lead at Chicago-O'Hare International Airport are contained in Table 60. It can again be seen that the air quality standards are exceeded for the first three pollutants, while the potentially harmful level is exceeded for lead.

For particulates, the primary and secondary standards are both exceeded at three receptor locations. The locations are at the heads of runways and have a 70 per cent aircraft contribution.

For nitrogen dioxide, the primary and secondary standard is exceeded at twenty-nine receptor locations. The locations are categorized below with the percentage contribution from aircraft sources:

Five terminal locations - 9 per cent aircraft

Ten runway locations - 26 per cent aircraft

Eight boundary locations - 10 per cent aircraft

Six surrounding locations - 4 per cent aircraft

For sulfur dioxide, the primary standard is exceeded at one receptor location - a runway location with 78 per cent aircraft contributions. The secondary standard is exceeded at two additional receptors - both runway locations with 65 per cent aircraft contributions.

For lead, the potentially harmful level is exceeded at locations which have negligible aircraft contributions.

Van Nuys Airport

Annual average concentrations for particulates, nitrogen dioxide, sulfur dioxide, and lead at Van Nuys Airport are contained in Table 61. It can be seen that air quality standards are not exceeded by the first three pollutants, but there is one receptor at which the lead concentration due to aircraft emissions is nearly equal to the potentially harmful level.

New Tamiami Airport

Annual average concentrations for particulates, nitrogen dioxide, sulfur dioxide, and lead at New Tamiami Airport are contained in Table 62. It can be seen that air quality standards are not exceeded by the first three pollutants, and the potentially harmful level is not exceeded by lead.

Isopleths of Annual Average Concentrations

The impact of aircraft emissions upon an airport and its surroundings can be visualized by preparing isopleths of pollutant concentration. As an example, isopleths of nitrogen dioxide concentrations have been prepared for Los Angeles International Airport.

Nitrogen Dioxide Isopleths of the Airport

Annual average concentrations of nitrogen dioxide at receptors within LAX and on the boundary, as given in Table 59, are used to construct Figures 33 and 34. Figure 33 shows the nitrogen dioxide isopleths of concentration from aircraft sources. The hot spots at the heads of the runway show up clearly. Two parallel ridges ($20\mu\text{g}/\text{m}^3$ isopleths) reflect the geometry of the runway system and the predominance of east-west winds. Figure 34 shows the nitrogen dioxide isopleths from all emissions sources. It can be seen that the runway ridges lose their prominence, and a hot spot at the heating plant and terminal buildings is added to hot spots at two of the runway heads. The prevailing east-west winds are also seen to be reflected in the geometry of the isopleths.

Nitrogen Dioxide Isopleths in the Airport Vicinity

Annual average concentrations of nitrogen dioxide at receptors on the boundary of LAX and in the surroundings, from Table 59, are used to construct Figures 35 and 36. Figure 35 shows nitrogen dioxide isopleths in the airport vicinity from aircraft sources. Figure 36, on the other hand, shows nitrogen dioxide isopleths in the airport vicinity from all sources. The geometry of the isopleths are rather similar, and reflect again the prevailing east-west winds. The isopleths of Figure 36, however, are generally about a factor of 10 greater than those of Figure 35 and exhibit a more widespread geometry.

Short-Term Concentrations

In the calculation of short-term maxima concentrations, the length of the time periods considered were based upon the specified periods of the air quality standards. Hence, calculations were performed for the following time periods:

- 1 hour
- 6 am to 9 am
- 3 hour
- 8 hour
- 24 hour

Due to the variation of meteorological conditions in a 24-hour period, that time period was further subdivided into three 8-hour periods.

The worst combination of meteorological conditions from an air pollution viewpoint were then sought for each time period at the selected airports using local 3-hour observations. The resulting meteorological conditions, together with other pertinent data, are presented in Tables 63 through 67 for DCA, JFK, LAX, ORD, and Tamiami, respectively. These combinations of worst meteorological conditions are typical of conditions which occur a number of times each year.

Results of the short-term calculations are presented below.

Washington National Airport

Short-term maxima concentrations for particulates, nitrogen dioxide, total hydrocarbons, carbon monoxide, and sulfur dioxide at Washington National Airport are contained in Tables 68a and 68b. Each pollutant which has a short-term air quality standard, exceeds the specified value at a number of receptor locations.

For particulates, the secondary standard is exceeded at six receptor locations. The locations are categorized below with the percentage contribution from aircraft sources:

Three runway locations - 60 per cent aircraft

One boundary location - 55 per cent aircraft

Two surrounding locations - 0 per cent aircraft

For non-methane hydrocarbons, the primary and secondary standard is exceeded at thirty-five receptors:

Four terminal locations - 2 per cent aircraft

Eight runway locations - 25 per cent aircraft

Fourteen boundary locations - 6 per cent aircraft

Nine surrounding locations - 1 per cent aircraft

For carbon monoxide, the primary and secondary 8-hour standard is exceeded at the heads of two runways with 85 per cent aircraft contributions. The primary and secondary 1-hour standard is exceeded at the heads of the same two runways with 95 per cent aircraft contributions, and at one boundary receptor with 75 per cent aircraft contributions.

For sulfur dioxide, the primary 24-hour standard is exceeded at one terminal receptor and two boundary receptors, both with negligible

aircraft contributions. The secondary 24-hour standard is exceeded at three additional receptors: two runway locations with 8 per cent aircraft contributions, and one surrounding location with negligible aircraft contributions. The secondary 3-hour standard is exceeded at a boundary and a surrounding location with essentially negligible aircraft contributions.

J. F. Kennedy International Airport

Short-term maxima concentrations for particulates, nitrogen dioxide, total hydrocarbons, carbon monoxide, and sulfur dioxide at J. F. Kennedy International Airport are contained in Tables 69a and 69b. Again, each pollutant which has a short-term air quality standard exceeds the specified value at a number of receptor locations.

For particulates, the primary standard is exceeded at eight receptor locations. The locations are categorized below with the percentage contribution from aircraft sources:

- One terminal location - 12 per cent aircraft
- Three runway locations - 55 per cent aircraft
- Three boundary locations - 12 per cent aircraft
- One surrounding location - 0 per cent aircraft.

The secondary standard is exceeded at fourteen additional receptors:

- Three terminal locations - 25 per cent aircraft
- One runway location - 45 per cent aircraft
- Three boundary locations - 33 per cent aircraft
- Seven surrounding locations - 4 per cent aircraft

For non-methane hydrocarbons, the primary and secondary standard is exceeded at forty-two receptors:

- Nine terminal locations - 60 per cent aircraft
- One roadway location - 20 per cent aircraft
- Eight runway locations - 60 per cent aircraft
- Twelve boundary locations - 40 per cent aircraft
- Twelve surrounding locations - 8 per cent aircraft

For carbon monoxide, the primary and secondary 8-hour standard is exceeded at nine receptor locations:

Five terminal locations - 30 per cent aircraft

Three runway locations - 80 per cent aircraft

One surrounding location - 0 per cent aircraft

The primary and secondary 1-hour standard is exceeded at five receptor locations:

Three terminal locations - 50 per cent aircraft

Two runway locations - 100 per cent aircraft

For sulfur dioxide, the primary 24-hour standard is exceeded at two terminals with a 2.5 per cent aircraft contribution. The secondary 24-hour standard is exceeded at four additional receptors:

Two runway locations - 18 per cent aircraft

One boundary location - 7 per cent aircraft

One surrounding location - 0 per cent aircraft

The secondary 3-hour standard is exceeded at two receptor locations: a terminal with negligible aircraft contributions, and a runway with 90 per cent aircraft contributions.

Los Angeles International Airport

Short-term maxima concentrations for particulates, nitrogen dioxide, total hydrocarbons, carbon monoxide, and sulfur dioxide at Los Angeles International Airport are contained in Tables 70a and 70b. Each pollutant which has a short-term air quality standard, except sulfur dioxide, exceeds the specified value at a number of receptor locations.

For particulates, the primary and secondary standards are exceeded at the heads of two runways with 95 per cent aircraft contributions.

For non-methane hydrocarbons, the primary and secondary standard is exceeded at thirty-five receptor locations:

Six terminal locations - 15 per cent aircraft

Eight runway locations - 60 per cent aircraft

Twelve boundary locations - 12 per cent aircraft

Nine surrounding locations - 5 per cent aircraft

For carbon monoxide, the primary and secondary 8-hour standard is not exceeded. However, the primary and secondary 1-hour standard is

exceeded at seven receptor locations:

Six runway locations - 90 per cent aircraft

One boundary location - 0 per cent aircraft

Chicago-O'Hare International Airport

Short-term maxima concentrations for particulates, nitrogen dioxide, total hydrocarbons, carbon monoxide, and sulfur dioxide at Chicago-O'Hare International Airport are contained in Tables 71a and 71b. Each pollutant which has a short-term air quality standard, exceeds the specified value at a number of receptor locations.

For particulates, the secondary standard is exceeded at three heads of runways with 70 per cent aircraft contributions.

For non-methane hydrocarbons, the primary and secondary standard is exceeded at twenty-nine receptor locations:

Three terminal locations - 100 per cent aircraft

Ten runway locations - 80 per cent aircraft

Eleven boundary locations - 75 per cent aircraft

Five surrounding locations - 25 per cent aircraft

For carbon monoxide, the primary and secondary 8-hour standard is exceeded at five locations:

One terminal location - 25 per cent aircraft

Four runway locations - 65 per cent aircraft

The primary and secondary 1-hour standard is exceeded at four locations:

One terminal location - 50 per cent aircraft

Two runway locations - almost 100 per cent aircraft

One surrounding location - 20 per cent aircraft

For sulfur dioxide, the primary and secondary 24-hour standards are exceeded at the head of one runway, with a 25 per cent aircraft contribution. The primary and secondary 3-hour standards are also exceeded at the head of one runway, with a 100 per cent aircraft contribution.

New Tamiami Airport

Short-term maxima concentrations for particulates, nitrogen dioxide, total hydrocarbons, carbon monoxide, and sulfur dioxide at New

Tamiami Airport are contained in Tables 72a and 72b. It can be seen that air quality standards are not exceeded for any pollutant.

Conclusions

As indicated above, it has been found that the national primary and secondary ambient air quality standards for particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, and non-methane hydrocarbons, respectively, were exceeded at a number of the selected air-carrier airports. However, the air quality standards, which have been set in accordance with the Clean Air Amendments of 1970, apply to areas to which the general public has access. In order to identify the seriousness of the aircraft contribution to the concentrations of a particular pollutant, some interpretation of this specification is necessary. Since the national primary ambient air quality standard for a pollutant is intended to protect the public health, consideration was limited to "reasonable access" areas. By definition, these are areas to which the general public has reasonable access for the averaging time specified in the pollutant standard. The same interpretation of "reasonable access" was used to apply the national secondary ambient air quality standards.* The "reasonable access" requirement for the air quality standards was also used in considering potentially harmful levels of lead concentrations.

Identification of "reasonable access" areas involves a judgement decision. Concerning the annual average concentrations of particulates, sulfur dioxide, and lead, only areas used for residences in the airport vicinities were considered to meet the "reasonable access" requirement. In these areas, there were no receptors for which the particulate concentration exceeded the air quality standard or the lead concentration exceeded the potentially harmful level. In the case of sulfur dioxide, there are three receptors at DCA located in such areas which exceed the secondary air quality standard. However, for those receptors, aircraft contributions

* A more stringent interpretation of "reasonable access" which might be used for the secondary standard, since it is intended to protect the public welfare, would be areas to which the public has access, regardless of averaging time.

are approximately 1 per cent. It is, therefore, concluded that aircraft emissions do not contribute significantly to excess annual average concentrations of particulates, sulfur dioxide, and lead in reasonable access areas.

Concerning annual average concentrations of nitrogen dioxide, again, only areas used for residences in the airport vicinities were considered to meet the "reasonable access" requirement. Of the receptor positions previously specified, the air quality standard is exceeded at 1 DCA receptor and 6 ORD receptors located in "reasonable access" areas. The aircraft contribution for these receptors is less than 4 per cent. As a percentage of the air quality standard, the maximum aircraft contribution is 6 per cent. However, as indicated in Appendix I, nitrogen dioxide concentrations at additional receptor locations had a maximum aircraft contribution of 19 per cent of the standard. Further, recently concluded measurements of aircraft exhaust emissions (see Ref 57) indicate that nitrogen oxide emission indexes used in this study were underestimated by a factor of approximately 3. On this basis, it is felt that aircraft emissions contribute significantly to excessive nitrogen dioxide concentrations in airport vicinities.

Concerning short-term maxima concentrations of particulates, total hydrocarbons, carbon monoxide, and sulfur dioxide, the "reasonable access" requirement also limited consideration in this case to certain areas. The areas are listed below for each time period:

1. 24-hour period - residential areas in the airport vicinity.
2. 8-hour period - residential areas, terminals.
3. 3-hour period - residential areas, terminals, airport boundaries, waterways.
4. 1-hour period - residential areas, terminals, airport boundaries, waterways, areas adjoining roadways.

The secondary 24-hour standard for particulates is exceeded at 3 DCA receptors and 7 JFK receptors located in "reasonable access" areas. However, aircraft contributions are negligible at the DCA receptors and only 4 per cent at the JFK receptors. The secondary 24-hour standard for sulfur dioxide is exceeded at 1 JFK receptor located in a "reasonable access" area, but the aircraft contribution is negligible. The secondary 3-hour standard for sulfur dioxide is exceeded at 2 DCA receptors and 1 JFK receptor located in "reasonable access" areas. For all three receptors the aircraft

contribution to the concentration is negligible. Hence, it has been found that aircraft emissions do not contribute significantly to excess short-term maxima concentrations of particulates and sulfur dioxide in reasonable access areas.

On the other hand, a quite different conclusion must be formulated concerning carbon monoxide and total hydrocarbon emissions. The 8-hour standard for carbon monoxide is exceeded at 6 JFK receptors and 1 ORD receptor located in "reasonable access" areas. Five of the JFK receptors are at terminals and have a 30 per cent aircraft contribution, while the sixth JFK receptor is in the surroundings and has a negligible aircraft contribution. The ORD receptor is at a terminal and has a 25 per cent aircraft contribution. The maximum aircraft contribution, at one of the JFK terminals, is 110 per cent of the air quality standard. The 1-hour standard for carbon monoxide is exceeded at 1 DCA receptor, 3 JFK receptors, 1 LAX receptor, and 2 ORD receptors located in "reasonable access" areas. Aircraft contributions to these values are generally considerable: 75 per cent at the DCA receptor, 50 per cent at the JFK receptors, and 35 per cent at the ORD receptors. The maximum aircraft contribution, at another of the JFK terminals, is 210 per cent of the air quality standard. Finally, the 6 am - 9 am standard for non-methane hydrocarbons is exceeded at 27 DCA receptors, 33 JFK receptors, 27 LAX receptors, and 19 ORD receptors located in "reasonable access" areas. Aircraft contributions to these values are, again, generally considerable: 3 per cent at the DCA receptors, 34 per cent at the JFK receptors, 10 per cent at the LAX receptors, and 65 per cent at the ORD receptors. There are a number of receptors for which the aircraft contribution, by itself, is an order of magnitude larger than the air quality standard. Hence, it must be said that predicted short-term maxima concentrations of non-methane hydrocarbons and carbon monoxide exceed the national primary and secondary ambient air quality standards at locations in the vicinity of major air-carrier airports.

Concerning the general aviation airports, there are no instances in which predicted concentrations exceeded air quality standards. In the case of lead, the potentially harmful level of concentration is approached but not exceeded. However, one case for which concentrations were not calculated - 8-hour and 1-hour concentrations of carbon monoxide at Van Nuys -

might have the potential of exceeding the air quality standard. This is suggested by the fact that the total emissions of carbon monoxide at Van Nuys is about 55 per cent of the DCA value, and DCA does have a receptor which exceeds the air quality standards in a "reasonable access" area.

EFFECTIVENESS OF CONTROL TECHNIQUES

Introduction

This section considers the effectiveness of control methods applied to aircraft engines and to airport ground operations. This is achieved by specifying new values for emission factors and calculating comparative concentrations to assess the improvement in over-all pollution levels. The control methods considered are listed below. They have been selected from those of Reference 6 as providing the greatest reductions.* The only control method concerning piston engines has been applied to New Tamiami Airport while all others have been applied to Los Angeles International Airport. The choice of New Tamiami results from the lack of available meteorological data at Van Nuys. Los Angeles International Airport has been selected because (a) the aircraft emissions represent a greater proportion of the total airport emissions than at J. F. Kennedy International Airport, (b) the mix of aircraft is more general than at Washington National Airport, and (c) the data available is more extensive than that of Chicago-O'Hare International Airport.

Control Method 1 - Combustion Chamber Redesign (Minor)

This method uses minor modifications of the combustion chamber and fuel nozzle to achieve the best existing state-of-the-art emission performance for turbine engines. The values for this control method have been obtained from Reference 6 and the emission indexes are listed in Table 73.

The results from this set of emission indexes will provide a datum against which to compare the improvement from the other control methods. In addition, the results of the calculation using this data will provide an indication of the slight improvement possible by implementing existing control methods. The results may also give some indication of the uncertainty existing

* Emission factors used in this analysis are based upon preliminary results from the program described in Reference 6. Final results in Reference 6 differ, in some instances, from the data used here.

in present measurements of emission levels.

Control Method II - Other Modifications Applicable to Existing Engines

This method combines three separate turbine engine modifications with Control Method I. Each additional modification affects different pollutants and may, therefore, be combined into one control method without confusing its individual contribution. The modifications are described below and the resulting emission indexes derived from the datum values in Table 73 are given in Table 74.

Control Method IIa - Combustion Chamber Redesign (Major)

This method consists of major modifications of the turbine engine combustion chamber and fuel nozzle, incorporating advanced fuel injection concepts of carburetion and fuel vaporization. The method may be expected to decrease particulate emissions to 50 per cent of levels for aircraft classes 3, 4, 5, and 6 during all modes of operation.

Control Method IIb - Divided Fuel Supply System

The provision of independent fuel supplies to subsets of fuel nozzles would allow the shutdown of one or more subsets during low power operation, thereby improving the operating conditions at other fuel nozzles. The consequent reduction of carbon monoxide and total hydrocarbon emissions at idle for class 2 aircraft would be to 50 per cent of the level associated with Control Method I and for classes 3, 4, 5, and 6 to 25 per cent.

Control Method IIc - Water Injection

The installation of a water injection system for short duration usage during take-off and climb-out, would reduce nitrogen oxide emissions to 25 per cent of the level associated with Control Method I for all turbine engine aircraft classes.

Control Method III - Methods Applicable to Future Engines

The controls discussed above are suitable for modifying existing aircraft turbine engines. Two methods which could be applied to future engines incorporate the use of variable airflow distribution, to provide independent control of combustion fuel-air ratio, and the use of advanced combustor design concepts, which involve a series of combustion zones with independently controlled fuel injection in each zone. The application of one or the other of these methods would result in the following emission levels, as a percentage of the levels associated with Control Method I:

		<u>Pollutant Emissions Index, Percentage of</u>			
<u>Aircraft Class</u>		<u>Carbon Monoxide</u>	<u>Nitrogen Oxide</u>	<u>Total Hydrocarbons</u>	<u>Particulates</u>
2	Idle	25	100	25	100
	Take-Off	100	25	100	100
3, 4	Idle	10	100	10	100
	Take-Off	100	50	100	50
5, 6	Idle	10	100	10	100
	Take-Off	100	50	100	100

These reduced levels are applied to the values in Table 73 and the new values of emission indexes are given in Table 75.

Control Method IV - Catalytic Reactors for Piston Engines

The use of catalytic reactors with low-lead fuel in piston engines may be expected to reduce the levels of emission indexes to the following percentages of existing levels:

Carbon Monoxide	10 per cent
Total Hydrocarbons	40 per cent
Lead	10 per cent

The resulting controlled levels are given in Table 76.

Control Method V - Increase in Idle Speed and Reduction of
Number of Engines Used

As a result of increasing the idle power setting for turbine engines, the emission indexes of carbon monoxide and total hydrocarbons may be reduced to more than offset the increase in fuel flow rate. If this increased power enables fewer engines to be used during the idle and taxi modes, a considerable reduction in emission factors results. The reduction in emission indexes with increased power has been approximated by taking the emission indexes resulting from a fuel flow rate twice that at idle conditions. This has been done for nitrogen oxide and particulates, as well as for carbon monoxide and total hydrocarbons, using Figures 37 through 40. The modified emission indexes are given in Table 77 together with the modified fuel flow at "high idle".

To obtain the effective number of engines per aircraft which operate during idle, the following equation is used:

$$Q = P \left(\frac{E_1 \times f_1}{1 + N_2/N_1} + \frac{E_2 \times f_2}{1 + N_1/N_2} \right) = eP$$

where Q = emission index per aircraft

P = emission index per engine

E = number of engines per aircraft

e = average number of engines operating per aircraft in class

f = fraction of engines used during idle and taxi

N = population of aircraft with E engines

and subscripts 1 and 2 are for aircraft with different numbers of engines.

It has been further assumed that

if E = 2 then f = 1

if E = 3 then f = 1/3

if E = 4 then f = 1/2

The following values have been obtained for e:

<u>Aircraft Class</u>	<u>All Engines Operating</u>	<u>Engines Operating in Taxi Mode</u>
2	4	2
3	4	2
4	2.6	1.4
5	2.5	2
6	2.1	1.95

Control Method VI - Use of Tractors to Move Aircraft in Ground Operations

It has been suggested that the use of tractors to move turbine-engine aircraft during ground operations may offer a means by which airport emissions can be reduced. Table 78 sets out the information required to obtain the effects of this control method. Typical values for two tractors were obtained from Reference 52. Emission indices for diesel engines were obtained from Reference 20. From the values contained in Table 78, the emission factors for the taxi and delay modes and the duration of the taxi mode may be obtained. It is assumed that the emission factors for idle and shutdown and start-up and idle are zero.

Emission Factors

The emission factors which result from each control method are set out in Tables 79 through 84. Each table (except for Table 82) contains the factors for aircraft classes 2 through 6, pollutants carbon monoxide, nitrogen oxide, total hydrocarbons and particulates for all aircraft operating modes. Table 82 applies to piston engined aircraft and lead is given in place of particulates. These values then represent the input data for the calculation of emissions and concentrations.

Time Periods

Two time periods have been used to obtain total emissions from aircraft and concentration levels at receptor points for Los Angeles

International Airport and New Tamiami Airport. The time periods selected are one hour and one year, which, while not covering all the standards set out in Table 55, will nevertheless provide a guide to the effectiveness of the various controls in meeting these standards.

Results of the Calculations

The effect of the control methods on concentrations and total emissions is given in Tables 85 through 105 for Los Angeles International Airport and New Tamiami Airport. Certain receptor points have been selected which reveal the effects of the controls on the most serious concentrations around the airport. The position of the receptor points may be obtained from Figures 25, 26, 31 and 32.

Tables 85 through 89 provide concentration levels for a 1 hour period for Los Angeles International Airport, and Tables 91 through 96 provide annual average values. Similarly, Tables 98 through 100 and 102 through 104 do the same for Tamiami Airport. In each table the uncontrolled value and the values with applicable controls are given. Also given in these tables are controlled emissions as a percentage of total airport emissions.

The predicted effects of control methods applicable to turbine engines on pollutant concentrations at LAX are as follows:

1. Control Method 1.

- a. Modest reductions of CO concentrations (20 to 50 per cent).
- b. Significant reductions in total hydrocarbon concentrations (60 to 75 per cent).
- c. No reduction in NO_x emissions.
- d. Large reductions in particulate emissions (50 to 80 per cent).

The predicted results actually indicate an increase in NO_x emissions with this control method. This predicted increase, however, is the result of the particular emission indexes used in calculating emission factors in this study. These emission indexes are actually below the "best-current" values estimated to be achievable for certain engines in Reference 6. The actual effect of Control Method 1 on NO_x concentrations is predicted to be a slight reduction, or no change at all.

2. Control Method II (in terms of concentrations with Control Method I).
 - a. Large reduction of CO concentrations (55 to 70 per cent).
 - b. Large reduction of total hydrocarbon concentrations (45 to 70 per cent).
 - c. Significant reductions in NO_x concentrations (30 to 65 per cent).
 - d. Significant reductions in particulate concentrations (35 to 50 per cent).
3. Control Method III (in terms of concentrations with Control Method I).
 - a. Large reductions in CO concentrations (70 to 85 per cent).
 - b. Large reductions in total hydrocarbon concentrations (60 to 90 per cent).
 - c. Significant reductions in NO_x concentrations (25 to 50 per cent).
 - d. Modest reductions in particulate concentrations (0 to 45 per cent).

Later estimates of the effectiveness of this control method in reducing particulate emissions (see Table 75) indicate that greater reductions can be expected than were predicted in this analysis.

4. Control Method V (in terms of concentrations with Control Method I).
 - a. Large reductions in CO concentrations (45 to 75 per cent).
 - b. Significant reductions in total hydrocarbon concentrations (30 to 55 per cent).
 - c. Slight increase in NO_x concentrations (0 to 20 per cent).
 - d. Significant increase in particulate concentrations (10 to 80 per cent).
5. Control Method VI (in terms of concentrations with Control Method I).
 - a. Large reduction in CO concentrations (50 to 95 per cent).
 - b. Large reduction in total hydrocarbon concentrations (55 to 97 per cent).
 - c. Slight increase in NO_x concentrations (0 to 10 per cent).

- d. Slight variations in particulate concentrations (-10 to +20 per cent).

The predicted effects of the control method applicable to piston engines (Control Method IV) on pollutant concentrations at New Tamiami Airport are:

1. Large reduction in CO concentrations (90 to 95 per cent).
2. Significant reduction in total hydrocarbon concentrations (approximately 60 per cent).
3. No change in NO_x concentrations.
4. Large reduction in lead concentrations (80 to 90 per cent).

Later estimates of the control effectiveness of this method on CO emissions (see Table 76) indicate that the reductions achieved in CO concentrations would be less than that listed above. A reduction of approximately 75 per cent, which still is considered large, appears to be a more likely result of the use of this method.

Conclusions

With regard to pollutant concentrations from turbine engine operations at air-carrier airports, the following conclusions can be drawn from these results:

1. Minor modifications of combustion chambers will produce large reductions in total hydrocarbon and particulate concentrations, and a lesser reduction in CO concentrations.
2. Minor modifications in ground operating procedures will further reduce CO and total hydrocarbon concentrations, but will increase particulate concentrations.
3. Simultaneous reductions in concentrations of CO, total hydrocarbons, NO_x , and particulates can only be achieved through a combination of combustor modifications (Method I) and other auxiliary control approaches (Method II), or by adopting new concepts of combustion chamber design (Method III).

With regard to pollutant concentrations from piston engines at general aviation airports, control devices developed for automobile engines can produce large reductions in CO and total hydrocarbon concentrations. The use of these devices may also force the use of low-lead gasoline, thereby reducing lead concentrations.

These results are based upon preliminary estimates of emission control effectiveness for various control methods, some of which have not been developed or tested as of yet. Therefore, the predictions are considered to be only qualitatively indicative of the effects on pollutant concentrations which would result from the use of these methods.

FUTURE PROJECTIONS OF EMISSIONS AND IMPACT

Introduction

The fourth task of the study was to develop projections of future emission rates and their impact at the selected airports. The results of that task are presented below.

Projected Emissions

The computer program for the air quality analysis of airports (Ref 7) was used to compute the total emissions for the years 1975 and 1980 at each of the selected airports except New Tamiami. Since New Tamiami is relatively new, no reliable projections of its future activity were available. In the computation, only aircraft and automobile activity levels and automobile emission factors were allowed to vary with time. The automobile emission factors which were used for 1975 and 1980 were presented earlier (see Table 9). On the other hand, the aircraft activity levels were calculated from the projected total activity in 1975 and 1980, the present mix of aircraft at the airport, and the change in the total population of each aircraft class during the elapsed time. All of this data has also been presented earlier. The resulting activity levels of each aircraft class at the selected airports are shown in Table 106. It can be seen that the general trend at the selected airports is towards more aircraft in classes 1, 2, 4, 6, and 7, and less aircraft in classes 3, 5, and 12. Finally, automobile activity was scaled from the number of available aircraft passenger seats.

The resulting total emissions at each airport are shown in Table 107. There are a number of general trends which can be seen. For aircraft sources at the air-carrier airports, the important trends are:

1. A small increase (approximately 20 per cent) in total particulate emissions.
2. A small increase (approximately 30 per cent) in sulfur dioxide emissions.
3. A large increase (approximately 200 per cent) in nitrogen oxide emissions.

4. A small decrease (approximately 10 per cent) in carbon monoxide emissions.
5. A large decrease (approximately 60 per cent) in total hydrocarbon emissions.

Since the average increase in the number of operations at the selected air-carrier airports during the 1970s is about 20 per cent, it can be seen that the newer aircraft have generally lower emissions. The one important exception is with regard to nitrogen oxide emissions where their performance is much poorer. The trend in the remaining pollutant shown in Table 107, lead, is not considered significant for air-carrier airports due to its relatively low magnitude.

For the sum of all airport sources at the air-carrier airports, the important trends are:

1. A small increase (approximately 10 per cent) in total particulate emissions.
2. A small increase (approximately 20 per cent) in sulfur dioxide emissions.
3. A substantial increase (approximately 40 per cent) in nitrogen oxide emissions.
4. A substantial decrease (approximately 30 per cent) in carbon monoxide emissions.
5. A large decrease (approximately 60 per cent) in total hydrocarbon emissions.
6. The virtual elimination of lead emissions.

The great progress anticipated in reducing automobile emissions is seen to have considerable effect in improving the projections of total airport emissions relative to the projections of aircraft emissions.

The important trend for aircraft emissions at the general aviation airport is a large increase (approximately 140 per cent) in carbon monoxide and lead emissions. The large increase is directly proportional to the projected activity increase at Van Nuys during the 1970's. For the sum of all airport sources at the general aviation airport, the projected increases in carbon monoxide and lead emissions are somewhat smaller (approximately 120 and 100 per cent, respectively). Again, this is due to the anticipated progress in reducing automobile emissions.

Projected Concentrations

Annual average concentrations for the years 1975 and 1980 at Los Angeles International Airport were also computed. The computation was based on the projected emission data discussed above. The results are shown in Tables 108 and 109 for 1975 and 1980, respectively. The pollutants in the tables are those for which annual national standards of ambient air quality exist. It can be seen that the change in concentrations between 1975 and 1980, due to aircraft sources at the various receptor points, follows quite closely the change in total aircraft emissions at LAX. Hence, the trends for aircraft emissions discussed above, can be extended to the concentrations due to aircraft sources at each of the selected airports. Similarly, the trends for total airport emissions discussed above can be extended to concentrations due to all sources at each of the selected airports. In this situation, however, the assumption is made that the contribution due to surrounding sources is rather small, which is not always true.

For the selected air-carrier airports, it is obvious that only in the case of nitrogen oxides will there be a substantial increase in concentrations. On the other hand, for the general aviation airports, the important increase in concentrations will be for lead and carbon monoxide.

Control of Projected Emissions

Due to the smaller projected emissions for some of the pollutants, their control will be less of a problem in the future than at present. For still other pollutants, their control in the future will be approximately the same problem as at present. As mentioned above, only in the case of nitrogen oxide for air-carrier airports and lead for general aviation airports will the control problem be substantially more severe in the future.

In the earlier section on control techniques it was indicated that the use of automotive emission control methods on aircraft piston engines could reduce carbon monoxide and lead emissions to 10 per cent of existing levels. Hence, these control methods could more than offset projected increases in emissions due to increased activity.

It was also indicated in the section on control techniques that the use of water injection could reduce nitrogen oxide emissions by approximately 50 per cent for turbine engines. Since the projected increase in nitrogen oxides emissions (due to increased activity and a different mix of aircraft for 1980) is 200 per cent, the use of water injection would still leave a 50 per cent increase in these emissions by 1980.

ANALYSIS OF UNBURNED FUEL EMISSIONS

Introduction

The final task of the study was to determine the practices of airlines with respect to disposal of unburned fuel, and the resulting total emissions and impact at the selected airports. The results of that task are presented below.

Disposal of Unburned Fuel

Design practice for turbojet engines currently in use by the scheduled airlines results in a certain amount of residual fuel in the system being collected in drain cans at shutdown. A smaller amount of fuel is also collected during engine start-up. The fuel in the drain cans is automatically siphoned from the cans by ram air pressure as the aircraft accelerates. This automatic venting has been a standard procedure on jet aircraft operated by the scheduled airlines. Attempts to force the airlines to manually drain the cans on the ground prior to take-off have been resisted.

C. W. Bristol, Jr., in Reference 17, explains how the fuel manifold in P & WA engines are drained:

"When an engine is shut down, the condition lever is moved to the cut-off position, which shuts off the flow of fuel from the fuel control.... the drop in fuel pressure causes the drain valve in the pressurizing and dump valve assembly to transfer to the dump position, thus venting the fuel manifold to atmosphere. Residual compressor discharge pressure in the combustion section forces the fuel out of the manifold to the drain, where it is collected in the drain tank in the aircraft nacelle."

Bristol then states the reasons for this design practice:

"This method of purging the fuel manifold was adopted to assure a rapid cut-off of fuel at shutdown and to preclude the possibility of a small fire continuing or of the residual fuel trapped in the combustion section spontaneously igniting following the initial flame-out. Another consideration in purging the manifold is to minimize any buildup of carbon due to the residual fuel trapped in the manifold."

Watkins (Ref 18) indicates that the drain cans empty themselves when the

aircraft reaches a 200 kt indicated air speed. This corresponds approximately to a 2000 ft altitude for typical climb-out paths of air-carrier aircraft.

Total Emissions

The total emissions due to automatic venting of the drain cans are based on the typical amounts of fuel drainage given by Bristol (Ref 17) for various engines. Given the average number of engines per aircraft in each class, the emission factors presented in an earlier section for the fuel venting mode (see Table 7) were obtained. The annual activity at the four selected air-carrier airports in this study then results in the following amounts of total hydrocarbon emissions for the year 1970:

Los Angeles International Airport - 4×10^5 kilograms
Washington National Airport - 1.2×10^5 kilograms
J. F. Kennedy International Airport - 3.3×10^5 kilograms
Chicago-O'Hare International Airport - 4.6×10^5 kilograms

Impact

The airlines have contended (see Ref18) that the vented fuel is immediately vaporized upon discharge and that wind currents prevent any measurable concentration on the ground. This contention was tested by considering a one-hour period of heavy activity at Washington National Airport when the meteorological conditions are conducive to relatively large concentrations. A total of twenty-three take-offs in aircraft classes 3, 4, and 5 were assumed to take place on runway 15-33 with the direction of movement being north. A straight climb-out path was used with the aircraft reaching a 900 meter altitude after traveling 6,030 meters. The assumed meteorological conditions were:

Wind direction - 320 deg (measured clockwise from the north)
Wind speed class 1 (0-3 mph)
Atmospheric stability class 1 (most unstable)
Wind persistence - 20 deg
Mixing height - 980 m

The most unstable class of atmospheric stability was selected because it

results in higher ground concentrations from high-altitude emissions. The instability results in greater vertical spread of the pollutant, allowing significant quantities to reach ground level over relatively short distances. Such conditions would tend to occur at periods when there are clear skies and high solar altitude (hence, large solar radiation), and low wind speeds. These conditions are most likely to occur around midday during late spring and summer.

The predicted isopleths of concentration of total hydrocarbons are shown in Figure 41. It can be seen that a relatively small area is subjected to concentrations greater than $15 \mu\text{g}/\text{m}^3$ (with a peak value of $18 \mu\text{g}/\text{m}^3$ being calculated), but approximately 500,000 sq m are subjected to concentrations over $10 \mu\text{g}/\text{m}^3$. Since the national primary standard for non-methane hydrocarbons due to all sources is a concentration of $160 \mu\text{g}/\text{m}^3$ and probably less than 10 per cent of the fuel is methane, it is evident that fuel venting, by itself, gives rise to fairly low levels of total hydrocarbon concentrations.

Considering the annual levels of emissions, fuel venting could be a more significant problem at the other air-carrier airports in the study. (However, the higher emissions at these other airports would be somewhat offset, in general, by more runways to handle the traffic.) In addition, the proximity of residential areas to the other airports in the study could intensify the problem.

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TABLES

TABLE 1 - CANDIDATE AIR-CARRIER AIRPORTS

<u>Airport</u>	<u>Total</u>	<u>Operations (FY 1970)</u> <u>(thousands)</u>			<u>Area</u> <u>(sq mi)</u>	<u>Wind Speed</u> <u>(mph)</u>	<u>Index</u> <u>(WAS)</u>
		<u>Air</u> <u>Carrier</u>	<u>General</u> <u>Aviation</u>	<u>Military</u>			
Chicago-O'Hare	671	634	34	3	6.7	11	23
Los Angeles	576	438	128	9	3.9	6.8	43
Atlanta	441	378	62	1	2.3	9.7	30
Dallas-Love	429	299	128	3	1.7	11	30
J. F. Kennedy	413	356	57	1	4.5	12	16
San Francisco	397	308	83	6	2.3	11	25
Miami	383	261	121	2	3.0	8.8	25
Denver	362	172	189	1	3.2	10	20
St. Louis	334	192	126	16	2.1	9.3	25
Washington National	334	220	111	3	1.0	9.7	34
La Guardia	333	265	67	1	1.0	13	26
Boston	329	217	111	1	2.1	13	17
Honolulu	325	129	129	66	1.8	12	20
Cleveland	322	145	178	1	1.8	12	21
Detroit	311	220	84	6	4.1	10	15
Washington Dulles	205	64	104	37	14.8	9.7	6

TABLE 2 - CANDIDATE GENERAL AVIATION AIRPORTS

<u>Airport</u>	<u>Total</u>	<u>Operations (FY 1970)</u> <u>(thousands)</u>			<u>Area</u> <u>(sq mi)</u>	<u>Wind Speed</u> <u>(mph)</u>	<u>Index</u> <u>(N/A/S)</u>
		<u>Air-</u> <u>Carrier</u>	<u>General</u> <u>Aviation</u>	<u>Military</u>			
Van Nuys	549	1	543	5	1.0	4.5	122
Long Beach	526	10	497	19	1.2	6.8	71
Ft. Lauderdale	505	46	464	5	1.6	8.8	46
Tamiami	509	0	505	4	1.4	8.8	49
Santa Ana	502	18	483	1	0.8	6.8	83
Opa Locka	493	0	481	12	2.0	8.8	40
Hollywood (Florida)	430	0	428	3	NA	8.8	-
San Jose	418	49	367	1	NA	7.5	-
Torrance	407	0	405	2	NA	6.8	-
Minnesota Flying Cloud	374	0	374	0	NA	11	-
Oakland	367	73	290	4	2.5	7.5	31
Phoenix	346	87	251	9	NA	5.4	-
Santa Monica	337	1	336	0	0.4	6.8	78
Ft. Worth Meacham	330	7	319	4	NA	13	-
San Diego Gillespie	319	0	318	1	NA	6.3	-
Louisville Bowman	317	0	316	1	NA	8.8	-
Hayward (California)	315	0	307	8	0.7	7.5	50

Note: NA indicates data is not available.

TABLE 3 - CANDIDATE MILITARY AIRPORTS

<u>Service</u>	<u>Airport</u>	<u>Total</u>	<u>Operations (CY 1969)</u>	
			<u>(thousands)</u> <u>Military</u>	<u>Civil</u>
<u>Air Force</u>	Craig AFB Selma, Ala.	572	571	1
	Laredo AFB Laredo, Tex.	607	606	1
	Laughlin AFB Del Rio, Tex.	432	431	1
	Moody AFB Valdosta, Ga.	537	536	1
	Reese AFB Lubbock, Tex.	489	487	2
	Vance AFB Enid, Okla.	668	666	2
	Webb AFB Big Spring, Tex.	424	420	4
	Williams AFB Phoenix, N. M.	529	529	0
	Fort Rucker, Ala. (21 fields)	4421	4376	45
	Fort Stewart, Ga. (21 fields)	2459	2446	13
	Fort Wolters, Tex. (28 fields)	1480	1477	3
<u>Army</u>	NAS Corpus Christi, Tex.	584	578	6
	NAAS Ellyson, Fla.	1398	1398	0
	NAAS Kingsville, Tex.	407	405	2
<u>Navy</u>	NAAS Meridian, Miss.	524	524	0
	NAS Pensacola, Fla.	343	342	1
	NAAS Saufley Field, Fla.	1114	1114	0
	NAAS Whiting Field, Fla.	722	721	1

TABLE 4 - AIRCRAFT CLASSIFICATION SYSTEM

Category	Aircraft				Representative Engine			Engines per Aircraft
	Class	Ref 1 Classification	Type	Examples	Model	Type	Thrust or Power *	
Air-Carrier	1	-	Supersonic Transport	Concorde Tupolev TU-144	R-R/Snecma Olympus 593	Turbojet	39,000 lbf-t	4
	2	-	Jumbo Jet Transport	Boeing 747 Douglas DC-10	P&WA JT9D	Turbofan	43,000 lbf-t	4
	3	1	Long-Range Jet Transport	Boeing 707 Douglas DC-8	P&WA JT3D	Turbofan	18,000 lbf-t	4
	4	2	Medium-Range Jet Transport	Boeing 727 Douglas DC-9	P&WA JT8D	Turbofan	14,000 lbf-t	2.6
	5	4	Turboprop Transport	Lockheed Electra Fairchild Hiller FH-227	Allison 501-D13	Turbo-prop	3,800 hp	2.5
General Aviation	6	3	Business Jet	Lockheed Jetstar North American Sabreliner	P&WA JT12	Turbojet	2,900 lbf-t	2.1
	7	6	Piston-Engine Utility	Cessna 210 Centurion Piper 32-300 Cherokee Six	Continental 10-520-A	Opposed Piston	290 hp	1**
Military	8	-	Over 400,000 lbs Gross Weight	Boeing Stratofortress	P&WA TF33-P-3	Turbofan	17,000 lbf-t	NA
	9	-	100,000 lbs - 400,000 lbs Gross Weight	Lockheed Starlifter	P&WA TF33-P-7	Turbofan	21,000 lbf-t	NA

* Equivalent Shaft Power.

** Representative of Van Nuys and Tamiami.

Note: NA indicates data is not available.

TABLE 4 - AIRCRAFT CLASSIFICATION SYSTEM (CONTINUED)

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Aircraft					Representative Engine			Engine per Aircraft
Category	Class	Classification	Type	Examples	Model	Type	Thrust or Power*	
Military	10	-	10,000 lbs - 100,000 lbs Gross Weight	LTV Crusader	P&WA J57-P-20	Turbojet	18,000 lbf-t	NA
	11	-	Under 10,000 lbs Gross Weight	Cessna 172	Continental 10-360	Opposed Piston	210 hp	NA
V/STOL	12	7	Helicopters and V/STOL	Sikorsky S-61 Vertol 107	General Electric CT58	Turboshaft	1400 hp	2

* Equivalent Shaft Power.

Note: NA indicates data is not available.

TABLE 5a - ENGINE EMISSION DATA
IDLE MODE

Air-craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu-lates
					CO	NO _x	SO ₂	Alde-hydes	Re-active Hydro-carbons	Total Hydro-carbons		
1	Turbojet A	JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	1500	140	1.8 (NO only)	NA	3.5	NA	6.0	NA	NA
3	C1	JP5	0.0065	550	98	0.57	3.9	1.2	NA	62	NA	0.11
3	C2	JP4	0.0065	520	90	0.57	2.0	0.91	NA	70	NA	0.34
3	D1	JP5	0.0082	NA	92	<2.0	0.90	1.9	NA	64	NA	16* or 0.37
3	D2	JP4	0.0075	490	170	0.34	0.32	2.0	NA	75	NA	0.30
3	D3	JP5	0.0087	550	120	0.12	0.91	1.8	NA	56	NA	0.37
3	E1	JP4	0.0061	770	76	1.0	0.36	2.3	NA	42	NA	0.27
3	E2	JP5	0.0065	760	170	0.90	12	1.9	NA	82	NA	0.67
3	E3	JP5	0.0068	NA	80	<1.7	1.1	0.34	NA	38	NA	0.31
3	E4	NA	0.0076	690	69	1.8	NA	3.8	20	NA	NA	69
3	E5	Aviation Kerosine	0.0059	670	NA	NA	NA	1.4	NA	16	NA	NA
3,4	F	Aviation Kerosine	0.0099	520	NA	1.3	NA	0.88	NA	10	NA	NA
6	G	JP5	0.0086	260	100	0.58	2.8	0.81	NA	12	NA	0.13
8,10	H1	JP5R	0.0075	NA	48	1.9	NA	NA	NA	17	NA	62 (Low rpm)
8,10	H2	JP4	0.0052	400	23	3.8	NA	0.45	NA	13	NA	NA
10	I	JP5	NA	NA	130	2.0	(0.2)	NA	NA	46	NA	0.05 (as C)
NA	J	JP4	0.0079	250	120	0.69	0.17	0.55	NA	12	NA	0.12

Note: Parentheses are for calculated values.

Note: NA indicates data is not available.

* Includes condensed hydrocarbons.

TABLE 5a - ENGINE EMISSION DATA
IDLE MODE - (CONTINUED)

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Air-craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Particu-lates	
					CO	NO _x	SO ₂	Alde-hydes	Re-active Hydro-carbons	Total Hydro-carbons		Lead
2	Turbofan	JP4	NA	NA	30	1.1	0.7	0.2	NA	5.0	NA	NA
		JP5	0.0085	NA	61	<2.0	0.9	0.25	NA	15	NA	51* or 1.5
2	K3	NA	0.010	700	53	2.5	NA	1.5	<1.5	NA	NA	NA
2	L	JP5	NA	NA	50	3.5	(0.2)	NA	NA	17	NA	0.04 (as C)
3,4,6	M	NA	0.0056	380	140	9.5	NA	NA	NA	1.5	NA	0.2(as C)
	N	JP5	NA	NA	180	1.5	(0.2)	NA	NA	51	NA	NA
	O1	JP4	0.0076	420	50	2.4	0.29	0.15	NA	9.6	NA	0.59
	O2	JP5	0.0092	390	67	0.60	0.07	0.057	NA	9.2	NA	0.85
	O3	JP5	0.0074	NA	77***	< 2.0	NA	0.47	NA	15***	NA	77% or 0.41
4,6	O4	Aviation Kerosine	0.0038	460	98	3.1	NA	0.99	NA	28	NA	NA
8,9,10	P	JP4	0.0065	450	28	2.6	NA	3.2	NA	49	NA	NA
	Q	JP4	0.0072	400	58	1.7	NA	8.1	NA	48	NA	NA
	R	JP5	NA	NA	50	3.5	(0.2)	NA	NA	17	NA	0.04(as C)
5	Turboprop	JETA1	0.0094	230	25	5.7	NA	NA	NA	8.1	NA	0.6
		JP4	0.008	310	9.2	1.6	NA	0.44	NA	5.1	NA	2.4
		JP5	NA	NA	150	0.7	(0.2)	NA	NA	91	NA	NA
9,10		Average Gasoline	0.086	15***	900	6.6	NA	NA	NA	37	NA	NA
12	Piston	Mostly 80 Octane (some 100)										
7,11	V											

*Includes condensed hydrocarbons.

**First number is smokeless and the second is smoky.

***Idle run-up mode.

Note: Parentheses are for calculated values.

Note: NA indicator data is not available

TABLE 5b - ENGINE EMISSION DATA
APPROACH MODE

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons		
1	Turbojet A B C1 C2 D1	JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		JP5	0.0092	1800	11	2.6	1.4	<0.023	NA	11	NA	1.0
		JP4	0.0092	1700	8.7	2.0	0.34	1.5	NA	3.2	NA	0.88
		JP5	0.013	NA	5.7	NA	0.91	1.1	NA	1.8	NA	31* or 1.2
3	D2 D3 E1 E2 E3	JP4	0.0097	2300	8.7	3.0	0.91	0.23	NA	16	NA	1.1
		JP5	0.01	2300	7.1	2.9	1.9	1.3	NA	9.8	NA	1.6
		JP4	0.0084	2200	8.7	2.3	<0.026	0.099	NA	3.5	NA	0.65
		JP5	0.0089	2100	12	2.9	2.11	0.035	NA	8.6	NA	1.3
		JP5	0.0097	NA	10	2.0	0.90	<0.022	NA	1.6	NA	0.72
3	E4 E5 Aviation Kerosine Aviation Kerosine	NA	0.0082	1800	15	5.0	NA	2.0	<2.5	NA	NA	6.3
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3,4	F G H1 H2 I	JP5	0.011	800	11	2.3	2.1	<0.019	NA	0.76	NA	0.49
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		JP4	NA	NA	5.0	5.8	NA	0.073	NA	2.3	NA	NA
		JP5	NA	NA	21	8.0	(0.2)	NA	NA	5.7	NA	0.08 (as C)
		JP4	0.011	800	12	2.5	0.081	0.038	NA	0.60	NA	0.44

* Includes condensed hydrocarbons.

** 50 per cent power.

Note: Parentheses are for calculated values.

Note: NA indicates data is not available.

TABLE 5b - ENGINE EMISSION DATA
APPROACH MODE - (CONTINUED)

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Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active hydro- carbons	Total Hydro- carbons		
2	Turbofan	JP4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	K1	JP5	0.012	NA	5.1	3.7	0.91	0.017	NA	5.0	NA	25* or 0.41
2	K2	NA	0.012	2500	5.0	8.0	NA	1.5	1.4	NA	NA	8.3
3, 4, 5	L	JP5	NA	NA***	3.0	28	(0.2)	NA	NA	0.34	NA	0.07 (as C)
4, 6	M	NA	0.0062	1100	18	6.7	NA	NA	NA	about 3	NA	0.6 (as C)
4, 6	N	JP5	NA	NA***	75	2.7	(0.2)	NA	NA	2.3	NA	NA
4, 6	O1	JP4	0.0093	1300	6.6	3.4	0.15	0.067	NA	1.4	NA	2.7
4, 6	O2	JP5	0.011	1500	5.0	2.8	0.058	0.046	NA	0.57	NA	2.8
4, 6	O3	JP5	0.011	NA	4.6	3.2	NA	0.019	NA	0.19	NA	24* or 0.46
4, 6	O4	Aviation Kerosine	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8, 9, 10	P	JP4	0.012	2400	2.4	2.0	NA	0.027	NA	2.1	NA	NA
NA	Q	JP4	0.013	1300	5.8	5.4	NA	0.48	NA	0.41	NA	NA
NA	R	JP5	NA	NA***	3.0	28	(0.2)	NA	NA	0.34	NA	0.07 (as C)
5	Turboprop	JETA1	0.0075	400	1.6	4.4	NA	NA	NA	0.0	NA	1.0
9, 10	S	JP4	0.014	690	3.1	3.0	NA	0.13	NA	0.075	NA	2.0
12	T	JP5	NA	NA***	18	1.5	(0.2)	NA	NA	3.3	NA	NA
7, 11	U	Average Gasoline Mostly 80 Octane (some 100)	0.086	6.3 ***	830	3.4	NA	NA	NA	120	NA	NA

Note: Parentheses are for calculated values.
Note: NA indicates data is not available.

* Includes condensed hydrocarbons.
** 50 per cent power.
*** First approach mode.

TABLE 5c - ENGINE EMISSION DATA
TAKE-OFF MODE

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons		
1	Turbojet	JP5	NA	NA	NA	14 ^{***} 20 ≤17 (NO only)	NA	NA	NA	NA	NA	NA
1	B	NA	NA	13000	3 ^{***} ≤9	4.3	1.0	≤0.2	NA	≤0.2	NA	≤0.2 (as C)
3	C1	JP5	0.016	5200	0.93	3.6	≤0.013	≤0.013	NA	0.39	NA	≤0.78
3	C2	JP4	0.016	5100	0.98	8.0	0.91	0.025	NA	0.12	NA	≤0.59
3	D1	JP5	0.017	NA	0.99	1.8	0.12	0.016	NA	0.23	NA	15% or 0.66
3	D2	JP4	0.013	4300	0.73	1.6	5.2	0.031	NA	0.079	NA	0.57
3	D3	JP5	0.014	4300	0.72	1.2	≤0.014	0.013	NA	0.31	NA	0.87
3	E1	JP4	0.016	6400	0.63	1.2	1.2	0.013	NA	0.47	NA	0.63
3	E2	JP5	0.016	6300	1.1	6.9	0.91	0.013	NA	0.15	NA	1.5
3	E3	JP5	0.015	NA	1.1	11	NA	0.014	NA	0.04	NA	1.2
4	E4	NA	0.017	5700	≤0.5	NA	NA	1.8	≤2.5	NA	NA	5.3
3	E5	Aviation Kerosine	0.012	4500	NA	9.0	NA	0.1	NA	0.11	NA	NA
3,4	F	Aviation Kerosine	0.014	3800	NA	1.6	NA	NA	NA	0.14	NA	NA
6	G	JP5	0.017	1500	3.8	7.6	1.9	0.012	NA	0.33	NA	0.41
8,10	H1	JP5R	0.013	NA	2.7	6.5	NA	NA	NA	1.0	NA	98 (high rpm)
8,10	H2	JP4	0.014	3800	2.1	18	NA	0.06	NA	0.17	NA	NA
10	I	JP5	0.017	NA	3.5	1.6	(0.2)	NA	NA	1.1	NA	0.1 (as C)
NA	J	JP4	NA	1500	3.9	1.6	0.064	≤0.012	NA	0.29	NA	0.31

* Includes condensed hydrocarbons.

Note: NA indicates data is not available.

*** First number is without afterburner and second number is with afterburner.

Note: Parentheses are for calculated values.

TABLE 5c - ENGINE EMISSION DATA
TAKE-OFF MODE - (CONTINUED)

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons		
2	Turbofan	JP4	NA	NA	<1.0	3.1	0.8	<0.02	NA	0.1	NA	0.1
2	K1	JP5	0.021	NA	<0.07	10	0.91	<0.01	NA	<0.05	NA	7.6* or
2	K2	NA	0.016	7100	<0.5	26	NA	1.4	<1.0	NA	NA	0.24
2	K3	JP5	NA	NA	0.5	40	(0.2)	NA	NA	0.11	NA	6.5
3, 4, 6	L	NA	0.011	3400	1.1	14	NA	NA	NA	<2.0	NA	0.04 (as C)
4, 6	M	JP5	NA	NA	39	2.8	(0.2)	NA	NA	0.8	NA	2.2 (as C)
4, 6	N	JP4	0.015	3500	1.2	2.9	0.062	0.036	NA	0.56	NA	1.0 (as C)
4, 6	O1	JP5	0.018	4600	1.1	4.6	0.061	0.029	NA	0.18	NA	2.5
4, 6	O2	JP5	0.017	NA	<0.86	6.0**	NA	0.012	NA	0.04***	NA	2.2
4, 6	O3	Aviation Kerosine	0.065	3300	NA	6.2	NA	NA	NA	0.03	NA	NA
4, 6	O4	JP4	0.013	3900	0.35	0.62	NA	NA	NA	0.15	NA	20* or
8, 9, 10	P	JP4	0.013	3900	0.47	3.3	NA	0.0047	NA	0.32	NA	0.37
NA	Q	JP5	NA	NA	0.5	13	NA	0.14	NA	0.23	NA	NA
NA	R	JETA1	0.018	920	2.3	40	(0.2)	NA	NA	0.11	NA	0.04 (as C)
5	Turboprop	JP4	0.018	890	1.8	4.7	NA	NA	NA	3.2	NA	0.8
9, 10	S	JP5	NA	NA	14	3.8	(0.2)	0.25	NA	0.17	NA	1.9
12	U	Average Gasoline	0.084	33***	850	NA	NA	NA	NA	3.0	NA	0.3 (as C)
7, 11	Piston	Mostly 80 Octane (some 100)				6.1				13	NA	NA

* Includes condensed hydrocarbons.

*** First number is smokeless and the second is smoky.

**** Ascent mode.

Note: Parentheses are for calculated values.

Note: NA indicates data is not available.

TABLE 5d - ENGINE EMISSION DATA
CRUISE MODE

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)							Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons			
1 1 3 3 3	Turbojet A B C1 C2 D1	JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		
		JP5	0.013	3500	1.3	3.1	1.1	0.016	NA	1.33	NA	0.99	
		JP4	0.013	3600	2.0	2.8	0.051	1.4	NA	0.40	NA	0.80	
		JP5	0.015	NA	1.7	6.0	0.91	0.19	NA	0.32	NA	27* or	
		JP4	0.012	3900	0.98	2.2	0.39	0.017	NA	3.3	NA	0.80	
		JP5	0.013	4000	0.94	2.1	1.0	0.21	NA	6.4	NA	0.78	
		JP4	0.015	5800	1.2	1.7	0.015	0.014	NA	0.50	NA	0.96	
		JP5	0.015	5400	2.5	0.79	1.9	0.014	NA	0.16	NA	0.73	
3 3 3 3 3 3 3 3,4 6 8,10 8,10 10 NA	Turbojet D2 D3 E1 E2 E3 E4 E5 F G H1 H2 I J	JP5	0.014	NA	2.4	3.5	0.91	0.016	NA	0.16	NA	1.6	
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2	
		Aviation Kerosine	0.011	3700	NA	NA	NA	0.12	NA	NA	NA	NA	
		Aviation Kerosine	0.013	3000	NA	13	NA	0.15	NA	0.28	NA	NA	
		JP5	0.015	1200	5.5	2.0	1.9	0.014	NA	0.52	NA	NA	
		NA	NA	NA	NA	NA	NA	NA	0.39	NA	0.51		
		JP4	0.010	2500	5.0	5.8	NA	0.073	NA	2.3	NA	NA	
		JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		JP4	0.014	1200	5.8	2.1	0.079	0.015	NA	0.40	NA	0.37	

* Includes condensed hydrocarbons.

Note: NA indicates data is not available.

TABLE 5d - ENGINE EMISSION DATA
CRUISE MODE - (CONTINUED)

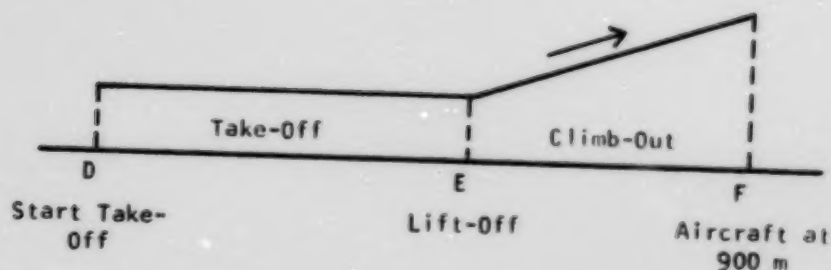
Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons		
2	K1	JP4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	K2	JP5	0.016	NA	1.2	6.1	0.91	<0.014	NA	<0.07	NA	10* or 0.31
2	K3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	L	JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3,4,6	M	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,6	N	JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,6	O1	JP4	0.013	2800	2.2	3.0	0.070	0.040	NA	0.65	NA	2.6
4,6	O2	JP5	0.016	3400	1.4	3.6	0.041	0.032	NA	0.28	NA	3.0
4,6	O3	JP5	0.015	NA	1.1	NA	NA	0.014	NA	0.06	NA	NA
4,6	O4	Aviation Kerosine	0.0055	2500	NA	11.0	NA	0.18	NA	0.21	NA	24* or 0.34
8,9,10	P	JP4	NA	NA	2.4	2.0	NA	0.027	NA	2.0	NA	NA
NA	Q	JP4	0.0082	3700	0.48	13	NA	0.095	NA	0.21	NA	NA
NA	R	JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5 9,10 12	Turboprop	JETA1	0.0075	410	1.6	4.4	NA	NA	NA	0.0	NA	1.0
		JP4	0.014	690	3.1	3.0	NA	0.13	NA	0.075	NA	2.0
		JP5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Average Gasoline Mostly 80 Oc- tane (some 100)	0.085	29**	860	4.22	NA	NA	NA	12	NA	NA

* Includes condensed hydrocarbons.

** Rich cruise mode.

Note: NA indicates data is not available.

TABLE 6a - AIRCRAFT PERFORMANCE CHARACTERISTICS DURING TAKE-OFF OPERATIONS



S_{DE} Distance D to E

V_E Velocity at E

t_{DE} Time to Travel D to E

S_{EF} Distance E to F

V_{EF} Average Velocity E to F

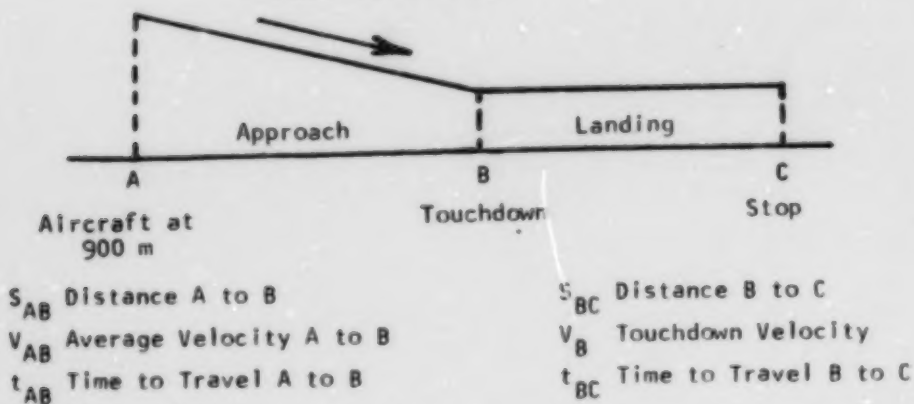
t_{EF} Time to Travel E to F

Class	S_{DE} m	V_E m sec ⁻¹	t_{DE} min	S_{EF} km	V_{EF} m sec ⁻¹	t_{EF} min	
1	1500	100	0.5	1.6	130	0.4	(No Noise Restriction)
				17		4.0	(Noise Procedure)
2	1900	81	0.7	6.0	89	1.8	
3	2800	93	1.0	8.1	98	2.2	
4	1900	81	0.8	6.5	91	1.9	
5	1000	54	0.6	11	79	3.6	
6	850	72	0.4	1.6	87	0.5	
7	470	37	0.4	6.3	67	2.5	
8	Use values for 2						
9	Use values for 3						
10	Use values for 6						
11	Use values for 7						
12	0	0	0.0	24	61	6.5	

Assumed Conditions:

- (a) Runway at sea level.
- (b) Zero runway slope.
- (c) Temperature 60 deg F.
- (d) Zero wind.
- (e) Aircraft at maximum load.

**TABLE 6b - AIRCRAFT PERFORMANCE CHARACTERISTICS DURING
LANDING OPERATIONS**



Class	S_{AB} km	V_{AB} m sec ⁻¹	t_{AB} min	S_{BC} m	V_B m sec ⁻¹	t_{BC} min
1	15	86	2.8	(1000)	81	(0.4)
2	17	75	3.8	990	71	0.5
3	17	72	4.0	830	65	0.4
4	17	70	4.2	750	65	0.3
5	17	62	4.5	520	58	0.3
6	9.7	100	1.6	580	45	0.4
7	8.0	36	3.8	310	30	0.3
8	Use values for 2					
9	Use values for 3					
10	Use values for 6					
11	Use values for 7					
12	24	61	6.5	0	0	0

Assumed Conditions:

- (a) Runway at sea level.
- (b) Zero runway slope.
- (c) Temperature 60 deg F.
- (d) Zero wind.
- (e) Aircraft at maximum load.

Note: Parentheses indicate assumed value.

**TABLE 7 - DURATION OF GROUND OPERATIONS
AND FUEL VENTING DETAILS**

Class	Idle and Shutdown (secs)	Start-up and Idle (secs)	Idle Power (secs)	Cruise Power (secs)	Fuel Venting (kgms)
1	15	60	69	23	NA
2	15	60	69	23	1.965
3	30	60	69	23	2.340
4	15	60	69	23	1.046
5	15	60	69	23	1.303
6	5	60	69	23	NA
7	5	60	69	23	NA

Note: NA indicates data is not available.

TABLE 8a - AUXILIARY POWER UNIT EMISSIONS
(GTCP-85-98 CK UNIT)

Operating Condition	Pollutants (kgms per hour)							
	CO	NO _x	SO ₂	Aldehydes	Reactive Hydrocarbons	Total Hydrocarbons	Lead	Particulates
Idle	1.46	0.132	NA	NA	NA	0.141	NA	NA
Full Bleed, 120 SHP*	0.902	0.467	NA	NA	NA	0.0181	NA	NA

Note: NA indicates data is not available.

* An auxiliary power unit is a source of both compressor bleed air and shaft power.

TABLE 8b - ESTIMATE OF AUXILIARY POWER UNIT DUTY CYCLE IN SERVICE

Mode	Description	Operating Conditions	Approximate time in mode, (minutes)			
			Class 2	Classes 3 & 4	Class 6	
Descent	Approach of airliner to airport	Inoperative	0	0	0	
Taxi	Light-off of APU after termination of main engine thrust reversal and taxi to ramp	100 per cent bleed/shp	5	5	5	
Park	Airliner serviced, cleaned, refueled, and passenger loading	100 per cent bleed/shp	80	40	20	
Taxi	Taxi to end of runway	100 per cent bleed/shp	10	10	10	
Ascent	Ascent to cruise altitude	Shutdown	5	5	5	

TABLE 9 - AUTOMOBILE EMISSIONS

Year	Pollutants (gms per kilometer)							
	CO	NO _x	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1970	49	4.1	0.11	0.22	NA	8.4	0.15	0.19
1975	30	3.1	0.11	0.22	NA	4.2	0.05	0.06
1980	12	1.4	0.11	0.22	NA	1.4	0.01	0.02

Note: NA indicates data is not available.

TABLE 10 - EMISSION FROM AIRPORT HEATING PLANT

Type of Fuel	Units	Pollutants							
		CO	NO _x	SO ₂	Aldehydes	Reactive Hydrocarbons	Total Hydrocarbons	Lead	Particulates
Fuel Oil	$\frac{\text{kqms}}{1000 \text{ liters}}$	0.005	13	19S* (S=1)	0.1	NA	0.6	0	1.0
Natural Gas	$\frac{10^3 \text{ m}^3}{1000 \text{ liters}}$	0.32	1.6	0.01	0.16	NA	0.13	0	0.3
LPG Butane	$\frac{\text{kqms}}{1000 \text{ liters}}$	0.84	4.2	0.04S (S=0.3)	0.42	NA	0.37	0	0.80
LPG Propane	$\frac{\text{kqms}}{1000 \text{ liters}}$	0.77	4.2	0.04S (S=0.3)	0.38	NA	0.34	0	0.73
Bituminous Coal	$\frac{\text{kqms}}{\text{tonne}}$	4.4	2.7	17S (S=4.3)	0.002	NA	1.3	0	0.9A** (A=9.1)
Anthracite	$\frac{\text{kqms}}{\text{tonne}}$	0.44	8	17S (S=0.5)	NA	NA	0.013	0	7.6A (A=10.1)

* S = Weight per cent Sulfur (Associated values in parentheses).

** A = Weight per cent Ash (Associated values in parentheses).

Note: NA indicates data is not available.

TABLE 11a - ENGINE EMISSION INDEXES
USED TO OBTAIN EMISSION FACTORS

Idle Mode

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)							
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	B	NA	NA	1500	140	1.8	1.0	3.5	NA	6.0	0.0	NA
2	K2 + K3	JP5	0.0085	700	61	2.0	1.0	0.25	NA	15	0.0	1.5
3	D3	JP5	0.0087	550	130	0.12	1.0	1.8	NA	56	0.0	0.37
4	O2	JP5	0.0092	390	67	0.60	1.0	0.06	NA	9.2	0.0	0.85
5	S	Jet A1	0.0094	230	25	5.7	1.0	NA	NA	8.1	0.0	0.6
6	G	JP5	0.0086	260	100	0.58	1.0	0.81	NA	12	0.0	0.13
7	V	Aviation Gasoline	0.086	15	900	6.6	NA	NA	NA	55	1.7	1.7
12	Data from Reference 1	-	0.0090	82	120	2.0	1.0	NA	NA	12	0.0	1.0

Note: NA indicates data is not available.

TABLE 11b - ENGINE EMISSION INDEXES
USED TO OBTAIN EMISSION FACTORS

Approach Mode

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)							
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	B	-	-	1500	140	1.8	1.0	3.5	NA	6.0	0.0	0.0
2	K2 + K3	JP5	0.012	2500	5.1	3.7	1.0	0.017	NA	5.0	0.0	0.41
3	D3	JP5	0.010	2300	7.1	2.9	1.0	1.4	NA	9.8	0.0	1.6
4	O2	JP5	0.011	1500	5.0	2.8	1.0	0.046	NA	0.57	0.0	2.8
5	S	Jet A1	0.0075	410	1.6	4.4	1.0	NA	NA	NA	0.0	1.0
6	G	JP5	0.011	800	11	2.3	1.0	0.019	NA	0.76	0.0	0.49
7	V	Aviation Gasoline	0.086	6.3	830	3.4	NA	NA	NA	180	1.7	1.7
12	Data from Reference 1	-	0.013	240	11	2.7	1.0	NA	NA	0.6	0.0	1.5

Note: NA indicates data is not available.

TABLE 11c - ENGINE EMISSION INDEXES
USED TO OBTAIN EMISSION FACTORS

Take-Off Mode

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)							
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	B	-	-	13,000	9.0	17	1.0	0.2	NA	0.2	0.0	0.2
2	K2 + K3	JP5	0.021	7100	0.07	10	1.0	0.010	NA	0.05	0.0	0.24
3	D3	JP5	0.014	4300	0.72	1.6	1.0	0.031	NA	0.31	0.0	0.87
4	O2	JP5	0.018	4600	1.1	4.6	1.0	0.029	NA	0.18	0.0	2.2
5	S	Jet A1	0.018	920	2.3	4.7	1.0	NA	NA	3.2	0.0	0.8
6	G	JP5	0.017	1500	3.8	1.6	1.0	0.012	NA	0.33	0.0	NA
7	V	Aviation Gasoline	0.084	33	850	6.1	0.2	NA	NA	20	1.7	1.7
12	Data from Reference 1	-	0.016	400	4.0	4.3	1.0	NA	NA	0.3	0.0	1.5

Note: NA indicates data is not available.

TABLE 11d - ENGINE EMISSION INDEXES
USED TO OBTAIN EMISSION FACTORS

Cruise Mode

Air- craft Class	Engine	Fuel	F/A	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)						Lead	Particu- lates
					CO	NO _x	SO ₂	Alde- hydes	Re- active Hydro- carbons	Total Hydro- carbons		
1	B	-	-	13000	9.0	17	1.0	0.2	NA	0.2	0.0	0.2
2	K2 + K3	JP5	0.016	5900	1.2	6.1	1.0	0.14	NA	0.07	0.0	0.31
3	D3	JP5	0.013	4000	0.94	2.1	1.0	0.21	NA	6.4	0.0	0.96
4	02	JP5	0.016	3500	1.4	3.6	1.0	0.032	NA	0.28	0.0	3.0
5	S	Jet A1	0.0075	410	1.6	4.4	1.0	NA	NA	NA	0.0	1.0
6	G	JP5	0.015	1400	5.5	2.0	1.0	0.01	NA	0.39	0.0	0.51
7	V	Aviation Gasoline	0.085	29	860	4.2	NA	NA	NA	18	1.7	1.7
12	Data from Reference 1	-	0.016*	320*	4.0*	4.3*	1.0*	NA	NA	0.3*	0.0	1.5*

* These values apply to climb-out mode.

Note: NA indicates data is not available.

TABLE 12a - EMISSION FACTORS

Operation: Idle and Shutdown

Air- craft Class	POLLUTANTS (gms)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	3400	45 (NO Only)	24	85	NA	150	0.0	0.0
2	710	23	12	2.9	NA	180	0.0	17
3	2300	2.2	18	32	NA	1000	0.0	6.8
4	280	2.5	4.2	0.24	NA	38	0.0	3.5
5	61	14	2.4	0.0	NA	20	0.0	1.5
6	78	0.44	0.75	0.0	NA	9.2	0.0	0.094
7	18	0.14	0.0	0.0	NA	1.1	0.034	0.034
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12b - EMISSION FACTORS

Operation: Start-Up and Idle

Air- craft Class	POLLUTANTS (gms)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	13,000	180 (NO Only)	97	340	NA	580	0.0	0.0
2	2,900	94	47	12	NA	700	0.0	69
3	4,600	4.4	37	65	NA	2,100	0.0	14
4	1,100	10	17	0.95	NA	150	0.0	14
5	240	55	9.8	0.0	NA	79	0.0	0.0
6	940	5.3	9.0	7.3	NA	110	0.0	0.0
7	220	1.6	0.0	0.0	NA	14	0.41	0.41
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12c - EMISSION FACTORS

Operation: Maintenance

Air- craft Class	POLLUTANTS (gms)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	16,000	5,700	440	460	NA	740	0.0	65
2	3,500	1,000	210	15	NA	820	0.0	130
3	5,400	220	140	95	NA	3,000	0.0	110
4	1,400	220	77	2.9	NA	190	0.0	190
5	290	92	18	0.0	NA	91	0.0	13
6	1,200	42	29	8.6	NA	130	0.0	10
7	410	2.6	0.0	0.0	NA	19	0.78	0.78
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12d - EMISSION FACTORS

Operation: Taxi, Idle at Runway

Air craft- Class	POLLUTANTS (gms per sec)							
	CO	NO _x	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	220	3.0	1.6	5.7	NA	9.7	0.0	0.0
2	47	1.6	0.78	0.19	NA	12	0.0	1.1
3	76	0.073	0.61	1.1	NA	34	0.0	0.23
4	19	0.17	0.28	0.016	NA	2.6	0.0	0.24
5	4.0	0.92	0.16	0.0	NA	1.3	0.0	0.097
6	16	0.088	0.15	0.12	NA	1.8	0.0	0.019
7	3.7	0.027	0.0	0.0	NA	0.23	0.0069	0.0069
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12e - EMISSION FACTORS

Operation: Approach

Air- craft Class	POLLUTANTS (gms)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	38,000	500	270	950	NA	1600	0.0	0.0
2	3300	2400	640	11	NA	3200	0.0	260
3	4400	1800	610	830	NA	6000	0.0	990
4	1400	770	280	13	NA	160	0.0	780
5	120	340	76	0.0	NA	0.0	0.0	76
6	490	100	45	0.85	NA	34	0.0	22
7	330	1.4	0.0	0.0	NA	70	0.66	0.66
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	580	140	53	0.0	NA	32	0.0	79

Note: NA indicates data is not available.

TABLE 12F - EMISSION FACTORS

Operation: Climb Out

Air- craft Class	POLLUTANTS (gms)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	31,000	57,000	3,400	680	NA	680	0.0	680
2	59	8,800	850	8.7	NA	42	0.0	200
3	450	980	600	19	NA	190	0.0	540
4	420	1,700	380	11	NA	68	0.0	820
5	320	660	140	0.0	NA	440	0.0	110
6	100	43	27	0.32	NA	8.8	0.0	11
7	1,200	8.4	0.0	0.0	NA	27	2.3	2.3
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	280	300	79	0.0	NA	21	0.0	100

Note: NA indicates data is not available.

TABLE 12q - EMISSION FACTORS

Operation: Landing Run - Constant Coefficient

Air- craft Class	POLLUTANTS (gms per meter)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	2.8	0.037	0.020	0.070	NA	0.12	0.0	0.0
2	0.67	0.022	0.011	0.0027	NA	0.17	0.0	0.016
3	1.2	0.0011	0.0094	0.017	NA	0.53	0.0	0.0035
4	0.29	0.0026	0.0043	0.00024	NA	0.040	0.0	0.0036
5	0.070	0.016	0.0028	0.0	NA	0.023	0.0	0.0017
6	0.35	0.0020	0.0033	0.0027	NA	0.041	0.0	0.00042
7	0.12	0.00090	0.0	0.0	NA	0.0076	0.00023	0.00023
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12h - EMISSION FACTORS

Operation: Landing Run - First Degree Coefficient

Air- craft Class	POLLUTANTS (gms per meter ² x 10 ⁴)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	52	0.69	0.38	1.3	NA	2.3	0.0	0.0
2	16	0.51	0.26	0.63	NA	3.9	0.0	0.38
3	25	0.024	0.20	0.36	NA	11	0.0	0.075
4	5.7	0.050	0.084	0.0048	NA	0.77	0.0	0.071
5	3.3	0.76	0.13	0.0	NA	1.1	0.0	0.08
6	10	0.058	0.100	0.081	NA	1.2	0.0	0.013
7	7.8	0.057	0.0	0.0	NA	0.48	0.015	0.015
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12i - EMISSION FACTORS

Operation: Take-Off Run - Constant Coefficient

Air- craft Class	POLLUTANTS (gms per meter)							
	CO	NO _x	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	4.0	7.5	0.44	0.089	NA	0.089	0.0	0.089
2	0.018	2.6	0.25	0.0026	NA	0.013	0.0	0.060
3	0.11	0.23	0.15	0.0046	NA	0.046	0.0	0.13
4	0.15	0.60	0.13	0.0038	NA	0.023	0.0	0.28
5	0.079	0.16	0.034	0.0	NA	0.11	0.0	0.028
6	0.15	0.060	0.038	0.0045	NA	0.012	0.0	0.016
7	0.59	0.0042	0.0	0.0	NA	0.014	0.0	0.0
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 12] - EMISSION FACTORS

Operation: Take-Off Run - First Degree Coefficient

Air- craft Class	POLLUTANTS (gms per meter ² x 10 ⁴)							
	CO	NOx	SO ₂	Alde- hydes	Reactive Hydro- carbons	Total Hydro- carbons	Lead	Particu- lates
1	-19	-35	-2.1	-0.41	NA	-0.42	0.0	-0.42
2	-0.058	-8.6	-0.82	-0.0084	NA	-0.41	0.0	-0.20
3	-0.25	-0.54	-0.35	-0.011	NA	-0.11	0.0	-0.30
4	-0.54	-2.2	-0.49	-0.014	NA	-0.087	0.0	-0.11
5	-0.52	-1.0	-0.22	0.0	NA	-0.72	0.0	-0.18
6	-1.1	-0.48	-0.30	-0.0036	NA	-0.098	0.0	-0.12
7	-8.0	-0.057	0.0	0.0	NA	-0.19	-0.016	-0.016
8	Use values for 2							
9	Use values for 3							
10	Use values for 6							
11	Use values for 7							
12	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0

Note: NA indicates data is not available.

TABLE 13 - HOURLY OPERATIONS AT LOS ANGELES INTERNATIONAL AIRPORT

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Percentage of Operations	4	2	1	.3	.5	.3	.9	2	5	6	6	6	7	6	6	5	5	5	5	6	5	7	5	4

Sources: References 22 and 24.

TABLE 14 - HOURLY OPERATIONS AT WASHINGTON NATIONAL AIRPORT

May, 1970

Day	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
Fri	1	0	3	2	0	2	1	2	31	56	61	59	62	56	52	65	55	65	49	73	58	53	43	42	10	900
Sat	2	1	2	0	2	2	0	4	33	47	62	51	47	37	38	44	52	35	45	44	42	34	29	13	2	666
Sun	3	1	3	3	0	0	0	1	14	24	34	38	37	44	44	44	54	55	59	58	59	44	54	39	6	715
Mon	4	2	0	0	0	1	1	3	35	63	60	65	60	57	56	54	60	58	62	55	45	38	53	27	5	860
Tues	5	3	1	3	3	0	0	4	41	75	67	65	59	57	53	68	77	73	72	57	52	37	54	27	8	956
Wed	6	2	2	2	2	0	0	3	34	69	71	63	65	57	52	66	65	65	64	66	52	44	50	30	5	929
Thurs	7	3	2	1	1	0	0	4	44	61	62	56	61	56	48	65	72	76	80	66	51	43	47	35	12	946

November, 1970

Day	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
Sun	1	1	0	0	0	0	0	2	17	22	36	37	45	46	43	40	44	58	56	63	40	40	49	27	6	672
Mon	2	2	1	1	0	0	0	5	34	55	63	61	52	49	51	44	53	52	57	60	47	40	42	28	9	806
Tues	3	1	0	0	2	0	0	1	29	53	53	53	48	53	47	46	52	56	66	54	49	43	46	25	11	788
Wed	4	2	1	0	0	1	0	6	33	68	59	52	16	56	62	50	51	31	37	55	57	50	52	33	13	785
Thurs	5	6	5	1	0	1	0	7	33	62	71	71	62	49	52	63	57	66	71	66	58	40	47	29	18	935
Fri	6	5	0	1	1	0	0	0	38	73	75	63	58	59	57	58	68	69	69	68	44	43	49	32	11	939
Sat	7	4	2	1	0	2	0	3	29	39	54	45	51	51	40	37	39	50	34	42	37	38	25	12	1	636

May, 1971

Day	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
Sat	1	1	3	1	3	0	1	6	34	40	54	46	55	57	50	40	41	40	35	44	39	36	32	13	1	672
Sun	2	0	3	0	1	0	0	3	21	30	37	39	47	50	48	55	50	60	64	63	59	48	51	29	6	764
Mon	3	1	0	0	0	0	2	6	37	57	64	53	65	71	46	56	51	67	61	70	55	48	51	28	3	892
Tues	4	2	2	0	3	1	0	5	39	64	79	53	57	62	55	52	70	73	71	63	54	52	53	24	8	942
Wed	5	4	2	0	2	2	1	9	46	62	75	67	66	71	61	59	68	88	84	62	59	52	50	30	3	1023
Thurs	6	1	2	0	2	1	1	6	36	69	70	65	64	69	61	62	76	79	77	66	60	51	53	35	6	1012
Fri	7	2	4	0	2	1	2	10	39	77	65	65	68	60	57	54	70	70	76	74	61	57	51	30	9	1004

Source: Reference 23.

TABLE 15 - HOURLY OPERATIONS AT J. F. KENNEDY INTERNATIONAL AIRPORT

May, 1970

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Air-Carrier	0	0	0	0	0	17	28	35	44	45	34	38	32	39	49	55	58	60	56	60	56	48	34	0
Other	0	0	0	0	0	3	5	8	5	7	6	6	11	6	10	12	10	11	8	11	5	6	4	0
Total	0	0	0	0	0	20	33	43	49	52	40	44	43	45	59	67	68	71	61	71	61	54	38	0

November, 1970

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Air-Carrier	0	0	0	0	0	20	22	29	44	39	35	36	37	32	48	53	57	54	55	50	50	36	18	0
Other	0	0	0	0	0	1	5	6	4	5	5	6	7	5	6	7	6	7	5	7	3	4	4	0
Total	0	0	0	0	0	21	27	35	48	44	40	42	44	37	54	60	63	61	60	57	53	40	22	0

Source: Reference 25.

TABLE 16 - HOURLY OPERATIONS AT CHICAGO-O'HARE INTERNATIONAL AIRPORT

May, 1970

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Air-Carrier	0	0	0	0	0	24	64	80	91	99	93	90	102	106	107	102	117	113	114	98	80	52	38	0
Other	0	0	0	0	0	1	2	5	9	5	6	5	5	6	8	9	9	7	7	5	4	6	2	0
Total	0	0	0	0	0	25	66	85	100	104	99	95	107	112	115	111	126	120	121	103	84	58	40	0

November, 1970

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Air-Carrier	0	0	0	0	0	14	62	74	85	89	74	84	95	99	91	94	101	108	105	80	64	42	23	0
Other	0	0	0	0	0	3	5	12	15	12	11	9	13	9	15	17	18	14	11	10	6	5	6	0
Total	0	0	0	0	0	17	67	86	100	101	85	93	108	108	106	111	119	122	116	90	70	47	29	0

Source: Reference 25.

TABLE 17 - AIR-CARRIER AIRPORT ACTIVITY VARIATION FOR A WEEK

Day of Week	Sun	Mon	Tues	Wed	Thu	Fri	Sat
Percentage of Mean Daily Activity	90	104	104	104	104	105	87

Source: Reference 24.

TABLE 18 - OPERATIONS BY MONTH AND YEAR FOR LOS ANGELES INTERNATIONAL AIRPORT

1970

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Air-Carrier	35260	31194	33957	32112	34108	35576	36255	26517	34743	34098	31320	32722
General Aviation					Not Available							
Military					Not Available							
Total Operations	46362	42928	47211	44635	47024	47538	49010	48348	45403	44243	39794	41577
Total Passengers	1651392	1396710	1655752	1510219	1694429	1972324	2136535	2279663	1742960	1575821	1456788	1708125

	1970	1975	1980
Air-Carrier	407,862	443,590	524,775
General Aviation*	119,724	NA	NA
Military	8,365	NA	NA
Helicopters	8,122	NA	NA
Total Operations	544,073	610,364	716,069
Total Passengers	20,780,718	24,802,000	31,299,500

Source: Reference 22.

* Includes scheduled commuter and civil movements.

Note: NA indicates data is not available.

TABLE 19 - OPERATIONS BY MONTH AND YEAR FOR WASHINGTON NATIONAL AIRPORT

1970/1971

	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	March
Air-Carrier	16802	18254	19229	18216	17805	17225	17792	17055	17412	17442	16223	18762
General Aviation	9240	10146	9364	8065	7992	8211	8505	7432	7413	7034	6860	9060
Military	203	257	372	272	373	499	403	290	241	293	514	99
Total Operations	26245	28657	28965	26553	26170	25935	26700	24777	25066	24769	23597	27921
Total Passengers	819639	880627	923377	817137	822722	770101	817002	787277	806352	752252	710997	838255

	1970	1975	1980
Air-Carrier	219,550	232,000	240,000
General Aviation	111,076	NA	NA
Military	2,922	NA	NA
Total Operations	333,548	339,500	347,000
Total Passengers	10,124,423	12,509,000	15,206,000

Sources: References 23 and 26.

Note: NA indicates data is not available.

TABLE 20 - OPERATIONS BY MONTH AND YEAR FOR J. F. KENNEDY INTERNATIONAL AIRPORT

1970

	Jan	Feb	March	Apr	May	June	July	August	Sept	Oct	Nov	Dec
Air-Carrier	30617	24877	26775	24102	26829	28962	33017	32747	30411	29104	25805	27193
General Aviation	4172	3836	4658	4777	6281	5237	4957	5260	4704	4426	3582	3609
Military						Not Available						
Total Operations	34789	28713	31433	28879	33110	34199	37974	38007	35115	33530	29387	30802
Total Passengers					Not Available							

	1970	1975	1980
Air-Carrier	377,500	358,500	365,000
General Aviation	NA	NA	NA
Military	NA	NA	NA
Total Operations	438,250	417,000	482,600
Total Passengers	18,953,500	25,224,000	41,216,000

Sources: References 26 and 27.

Note: NA indicates data is not available.

TABLE 21 - OPERATIONS BY MONTH AND YEAR FOR CHICAGO-O'HARE INTERNATIONAL AIRPORT

1970

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Air-Carrier	54497	49467	51213	43391	52641	54775	52798	52643	48193	47646	44882	46827
General Aviation	2463	2686	2441	2861	3066	3495	3489	2966	3953	5223	4995	4779
Military					Not Available							
Total Operations	56960	52153	53654	46252	55707	58270	56287	55609	52146	52869	49877	51606
Total Passengers					Not Available							

	1970	1975	1980
Air-Carrier	628,500	662,500	758,600
General Aviation	NA	NA	NA
Military	NA	NA	NA
Total Operations	679,750	714,000	821,600
Total Passengers	28,936,000	39,355,000	64,816,000

Sources: References 26 and 27.

Note: NA indicates data is not available.

TABLE 22 - OPERATIONS FOR THE GENERAL AVIATION AIRPORTS

VAN NUYS

Average Hourly Activity for March 1971

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
average Operations	3.5	2	.75	.5	.5	.5	4.25	31	66	87	109	120	126	136	135	150	149	123	66	29	22	12	8	5

Activity by Month for 1970-1971

Month	April	May	June	July	August	Sep	Oct	Nov	Dec	Jan	Feb	March
Air-Carrier	11	6	6	0	0	0	0	4	4	4	0	4
General Aviation	54168	52605	47902	57928	57228	49529	42703	40655	43929	36868	32749	42488
Military	428	416	415	390	303	339	326	263	323	295	428	362
Total	54607	53027	48323	58318	57531	49868	43029	40922	44256	37167	33177	42854

Composition of General Aviation Activity

97.8 Per Cent Single Engine Piston
1.8 Per Cent Two Engine Piston
0.4 Per Cent Business Jet

Activity by Year

Year	1970/71	1981
Air-Carrier	39	NA
General Aviation	558,752	NA
Military	5,288	NA
Total	563,079	1,418,000

Note: NA indicates data is not available.

TABLE 22 - OPERATIONS FOR THE GENERAL
AVIATION AIRPORTS (CONTINUED)

TAMiami

Operations per Hour Between 09.00 and
20.00 for 1971

100

Composition: Aircraft Almost All Single Engine Piston

Sources: References 28 , 29, 30, and 31.

TABLE 23 - ACTIVITY OF SELECTED MILITARY BASES

Base	Operations (CY 1969)			
	Type	Total	Military	Civil
Vance AFB	-	667,853	665,931	1,922
Laredo AFB	-	607,090	606,430	660
Fort Rucker Army Airfield				
Cairns AAF	Local	425,140	422,493	2,647
	Itinerant	31,300	8,101	23,199
Hanchey AHP	Local	296,333	296,333	0
Knox AHP	Local	70,839	70,839	0
Lowe AHP	Local	165,852	165,852	0
Corpus Christi NAS	Local	562,067	556,276	5,791
	Itinerant	21,698	21,409	289

Source: Reference 9.

TABLE 24 - TOTAL UNITED STATES CIVIL AIRCRAFT NUMBERS

Category	Ref. Definition	Approx. Class	1970	1975	1980
Air - Carrier	SST	1	0	33	86
	4-Engine Jet	2	37	411	759
		3	849	411	0
	2- and 3- Engine Jet	4	1,182	1,595	2,258
	Turboprop	5	380	278	181
General Aviation	Turbine	6	2,229	4,600	8,025
	Piston	7	124,586	155,500	196,250
V/STOL	Helicopters & Rotorcraft	12	2,575	3,825	5,406

Source: Reference 32.

TABLE 25 - ANNUAL ACTIVITY BY CLASS FOR AIR-CARRIER AIRPORTS IN 1969

Category	Class	Los Angeles Int.		Washington Nat.		J. F. Kennedy Int.		O'Hare Int.	
		Dep.	% Total	Dep.	% Total	Dep.	% Total	Dep.	% Total
Air-Carrier	3	105279	68	5	0	72223	55	83194	29
	4	38650	25	75247	69	52064	40	169092	59
	5	8793	6	31466	29	5940	5	29971	11
Piston Engine Transport		1277	1	3487	2	290	0	2830	1
Total Air-Carrier		153999		109205		130517		285087	

Source: Reference 33.

TABLE 26 - RELATIVE ACTIVITY OF RUNWAYS FOR LOS ANGELES
INTERNATIONAL AIRPORT

Runway	Direction of Movement	Per Cent Utilization	
		Landing	Take-Off
6L-24R	East	0.2	0.3
6L-24R	West	10.0	10.0
6R-24L	East	0.3	0.2
6R-24L	West	22.0	22.0
7L-25R	East	0.5	1.0
7L-25R	West	23.0	51.0
7R-25L	East	1.0	0.5
7R-25L	West	43.0	15.0

Source: Reference 34.

TABLE 27 - RELATIVE ACTIVITY OF RUNWAYS FOR WASHINGTON
NATIONAL AIRPORT

Runway	Direction of Movement	Per Cent Utilization	
		Landing	Take-Off
3-21	North	-	5
3-21	South	-	-
15-33	North	-	45
15-33	South	50	-
18-36	North	50	-
18-36	South	-	50

Source: Reference 29.

TABLE 28 - RELATIVE ACTIVITY OF RUNWAYS FOR J. F. KENNEDY
INTERNATIONAL AIRPORT

Runway	Direction of Movement	Per Cent Utilization	
		Landing	Take-Off
4L-22R	East	-	-
4L-22R	West	-	15.5
4R-22L	East	26.3	0.3
4R-22L	West	17.5	-
13L-31R	East	18.2	-
13L-31R	West	38.0	-
13R-31L	East	-	23.1
13R-31L	West	-	61.1

Source: Reference 34.

TABLE 29 - RELATIVE ACTIVITY OF RUNWAYS FOR O'HARE
INTERNATIONAL AIRPORT

Runway	Direction of Movement	Per Cent Utilization	
		Landing	Take-Off
4L-22R	East	8.7	1.1
4L-22R	West	5.0	0.3
4R-22L	East	10.0	0.8
4R-22L	West	5.0	10.0
9L-27R	East	13.8	15.3
9L-27R	West	1.2	2.6
9R-27L	East	5.8	8.8
9R-27L	West	2.2	13.2
14L-32R	East	5.0	5.3
14L-32R	West	13.6	24.6
14R-32L	East	15.4	6.4
14R-32L	West	13.7	8.0

Note: Reference does not supply 100 per cent of operations.

Source: Reference 34.

TABLE 30 - RELATIVE ACTIVITY OF RUNWAYS FOR GENERAL AVIATION AIRPORTSVan Nuys

Runway	Direction of Movement	Per Cent Utilization	
		Landing	Take-Off
16R-34L	North	74.3	40.5
16R-34L	South	25.7	59.5

Tamiami

Runway	Direction of Movement	Per Cent Utilization	
		Landing	Take-Off
9L-27R	East	25	25
9L-27R	West	13	13
9R-27L	East	25	25
9R-27L	West	13	13
13-31	East	16	16
13-31	West	8	8

Sources: References 29 and 31.

TABLE 31 - RELATIVE ACTIVITY BY AIRLINE FOR AIR-CARRIER AIRPORTS

Airline	Los Angeles International (Per Cent)	Washington National (Per Cent)	J. F. Kennedy International (Per Cent)	O'Hare International (Per Cent)
American	14	12	14	17
Eastern	0.0	27	14	5.4
Trans World	14	3.4	18	13
United	27	15	10	29
Pan Am	3.4	0.0	10	0.2
Braniff	0.1	1.3	2.3	2.8
Continental	4.3	0.0	0.0	2.4
Delta	3.4	1.5	3.9	7.8
National	2.5	8.1	9.3	0.0
Northeast	0.0	2.8	7.4	0.0
Northwest	0.0	6.5	0.0	8.3
Western	15	0.0	0.0	0.0
Allegheny	0.0	11	0.0	1.4
Mohawk	0.0	1.4	6.6	0.0
North Central	0.0	0.0	0.0	7.2
Ozark	0.0	0.0	0.0	5.3
Pacific	8.0	0.0	0.0	0.0
Piedmont	0.0	10	0.0	0.0
Other	8.1	0.0	3.9	0.8

Source: Reference 33.

TABLE 32 - DURATION OF TAXI AND IDLE AT RUNWAY MODES FOR AIRPORTSAir-Carrier

Airport	Mean Taxi Time min	Idle at Runway min
Los Angeles International	12	1.9
Washington National	8	2.5
J. F. Kennedy International	18	5.6
O'Hare International	18	4.3

Sources: References 35 and 36.

General AviationVan Nuys

Taxi time - No information
 Assume - Distance = 2,500 meters
 Speed = 15 kilometers per hour
 Time = 10 minutes
 Delay time - 3.5 minutes

Tamiami

Taxi time - No exact information
 Assume - Distance = 2,300 meters
 Speed = 11 kilometers per hour
 Time = 13 minutes
 Delay time - Negligible

Sources: References 30 and 31.

TABLE 33 - HEAT GENERATION AND FUEL STORAGE

Airport	Fuel	Heating Plant Size	Fuel Consumption liters/sec	Vapor* Emission gms/sec
Los Angeles International	Oil	4 x 200 hp 2 x 500 hp	14 hr/day, 5 day/wk, 0.0114 12 hr/day, 7 day/wk, 0.0114 Continuous, 0.0286	3.2
Washington National	Oil (No. 6 Bunker C)	2,750 hp	1.956 (Full load value based on 24-hr period) 0.317 (Based on annual value)	NA
J. F. Kennedy International	Oil	NA	4.20 (Peak) *** 0.68 (Mean)	2.6 [#]
O'Hare International	Natural Gas	NA	8.05 (Peak) *** 1.31 (Mean) (1.5 m ³ /sec)	4.1 [#]
Van Nuys	NA	NA	Assume zero	0.35***
Tamiami	No Heating Plant			

Sources: References 23, 30, 31, and 37.

* Assume 100 per cent of vapor emissions is hydrocarbons and 18.5 per cent is reactive hydrocarbons.

** Assuming fixed roof tanks.

*** Value obtained by weighting Washington National value for passenger activity and annual degree days.

[#] Value obtained from Los Angeles International value by weighting according to activity.

Note: NA indicates data is not available.

TABLE 34 - AUTOMOBILE ACTIVITY FACTORS

Airport	Given Information	Travel per Automobile	Automobiles per Aircraft Passenger Seat
Los Angeles International	1.33 vehicles per passenger 291,150 vehicle miles per day 252,954 vehicles per day	4.1 km	1.2
Washington National	60,000 operations/day 2 operations per auto 1.61 km per auto	1.6 km	1.0
J. F. Kennedy International	None	8 km ^{***}	1.1 [*]
O'Hare International	None	6 km ^{**}	1.1 [*]
Van Nuys	None	5 km ^{**}	1.2 ^{***}
Tamiami	100 employees, 1 auto per person Each instructor, 1 auto per 8 cycles Each student, 1 auto per cycle	1.6 km	1.2

* Mean of Los Angeles International and Washington National Airports.

** Measured from airport plan .

*** Based on Tamiami .

Aircraft Class	1	2	3	4	5	6	7
Passenger Seats	136	490	129	116	61	10	1

Sources: References 22, 23, 31, 37, 38, and 39.

TABLE 35 - EMISSIONS INDEXES FOR AIRPORT SURROUNDINGS

Emission Index (gms per sec per km ²) (S = Summer, W = Winter, A = Average)																
Area Type	SO _x			Particulates			CO			Hydrocarbons			NO _x			
	S	W	A	S	W	A	S	W	A	S	W	A	S	W	A	
City Center	63	71	56	9.3	11	8.3	140	120	130	23	20	21	19	19	17	
Urban	4.5	9.8	6.8	3.2	5.8	4.3	77	67	72	13	11	12	5.5	17	5.9	
Suburban	0.1	1.0	0.5	0.2	0.5	0.4	28	25	26	4.9	4.4	4.7	1.9	2.0	1.9	
Semi-Rural	0.06	0.25	0.16	0.16	0.19	0.16	12	11	11	1.9	1.7	1.8	0.79	0.79	0.76	
Rural	0	0.04	0.03	0.03	0.03	0.03	1.08	0.94	1.0	0.15	0.15	0.17	0.07	0.07	0.07	
Cemetery	Not Available															
Park	0	0.7	0.3	0.1	0.3	0.2	20	13	14	2.5	2.3	2.4	1.0	1.0	1.0	
Airport	1.4	1.4	1.4	4.7	4.7	4.7	15	15	15	23	23	23	4.0	4.0	4.0	

Source: Reference 40

TABLE 36 - MIXING HEIGHT OF THE ATMOSPHERE

Airport	Mean Annual Morning Mixing Height (m)	Mean Annual Afternoon Mixing Height (m)
Los Angeles International	540	930
Washington National	550	1400
J. F. Kennedy International	810	1200
O'Hare International	500	1200
Van Nuys	540	930
Tamiami	910	1400

Source: Reference 42.

TABLE 37 - SENSITIVITY OF CONCENTRATION PREDICTIONS TO METEOROLOGICAL
PARAMETERS

Parameter Name	Parameter Value	Per Cent Change of Concentration	
		Average Concentration	Maximum Concentration
Atmospheric Stability Class	Class 2	-27	-28
	Class 3	0	0
	Class 4	+9	+2
Wind Speed Class	Class 1 (1.5 mph)	+280	+270
	Class 2 (5.5 mph)	0	0
	Class 3 (10 mph)	-45	-44
Mixing Height	465 m	0	0
	930 m	0	0
	1860 m	0	0
Wind Direction	225 deg (SW)	-9	-14
	270 deg (W)	0	0
	315 deg (NW)	-18	-25
Wind Persistence	30 deg	+35	+34
	45 deg	0	0
	75 deg	-27	-35

TABLE 38 - COMPARISON OF ANNUAL AIRCRAFT EMISSIONS FOR 1970 AT LOS ANGELES INTERNATIONAL AIRPORT

Source of Results	Pollutants, kgms x 10 ⁻⁶				
	Particulates	Carbon Monoxide	Nitrogen Oxides	Total Hydrocarbons	Sulfur Dioxide
Model Calculation (Emissions below 3000 ft)	0.52	13	0.81	6.0	0.39
Reference 11 (Emissions below 3500 ft)	3.5	14	2.5	17	0.92

TABLE 39 - COMPARISON OF ANNUAL TOTAL EMISSIONS FOR 1970 AT LOS ANGELES
INTERNATIONAL AIRPORT

Source of Results	Pollutants, kgms x 10 ⁻⁶				
	Particulates	Carbon Monoxide	Nitrogen Oxide	Total Hydrocarbons	Sulfur Dioxide
Model Calculation (Emissions below 3000 ft)	0.56	25	2.0	7.9	0.43
Reference 11 (Emissions below 3500 ft)	3.7	26	3.3	21	1.1

TABLE 40 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS FOR THE YEAR 1970

POLLUTANT	AIRCRAFT			NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER		
CARBON MONOXIDE	1.381E+09*	2.943E+08	1.274E+09	4.986E+04		2.854E+11
NITROGEN OXIDES	5.017E+07	2.826E+08	1.066E+08	1.256E+08		2.179E+10
SULFUR DIOXIDE	2.512E+07	7.025E+07	2.860E+06	1.875E+08		1.555E+10
TOTAL PARTICULATES	2.948E+07	1.848E+08	4.939E+06	9.972E+06		1.041E+10
LEAD	2.931E+05	1.848E+05	3.899E+06	0.		NA
TOTAL HYDROCARBONS	1.952E+08	1.675E+08	2.184E+08	5.983E+06		4.806E+10
REACTIVE HYDROCARBONS	NA	NA	NA	NA		NA
ALDEHYDES	1.175E+06	2.178E+06	5.719E+06	9.972E+05		NA

* 1.381E+09 represents 1.381×10^9 in computer notation.

Note: NA indicates data is not available.

TABLE 41 - TOTAL EMISSIONS IN GRAMS AT J. F. KENNEDY INTERNATIONAL AIRPORT AND SURROUNDINGS FOR THE YEAR 1970

POLLUTANT	AIRCRAFT		NON-AIRCRAFT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	1.497E+10	9.217E+08	1.817E+10	1.070E+05	1.575E+11
NITROGEN OXIDES	9.998E+07	6.436E+08	1.817E+09	2.696E+08	1.129E+10
SULFUR DIOXIDE	0.6151E+08	3.180E+08	3.569E+07	4.022E+08	3.262E+09
TOTAL PARTICULATES	1.033E+08	4.121E+08	6.164E+07	2.140E+07	2.710E+09
LEAD	1.669E+05	4.097E+04	4.866E+07	0.	NA
TOTAL HYDROCARBONS	5.885E+09	1.091E+09	2.758E+09	9.552E+07	2.743E+10
REACTIVE HYDROCARBONS	NA	NA	NA	NA	NA
ALDEHYDES	1.770E+08	9.008E+07	7.138E+07	2.140E+06	NA

Note: NA indicates data is not available.

TABLE 4.2 - TOTAL EMISSIONS IN GRAMS AT LOS ANGELES INTERNATIONAL AIRPORT AND SURROUNDINGS FOR THE YEAR 1970

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	1.200E+10	1.151E+09	1.152E+10	6.170E+03	1.882E+11
NITROGEN OXIDES	9.183E+07	7.203E+08	1.152E+09	1.555E+07	1.345E+10
SULFUR DIOXIDE	0.4605E+08	3.438E+08	2.263E+07	2.320E+07	4.146E+09
TOTAL PARTICULATES	8.363E+07	4.388E+08	3.910E+07	1.234E+06	3.498E+09
LEAD	2.144E+05	8.296E+04	3.087E+07	0.	NA
TOTAL HYDROCARBONS	4.933E+09	1.413E+09	1.749E+09	1.027E+08	3.221E+10
REACTIVE HYDROCARBONS	NA	NA	NA	NA	NA
ALDEHYDES	1.516E+08	1.198E+08	4.527E+07	1.234E+05	NA

Note: NA indicates data is not available.

TABLE 43 - TOTAL EMISSIONS IN GRAMS AT CHICAGO-O'HARE INTERNATIONAL AIRPORT
AND SURROUNDINGS FOR THE YEAR 1970

POLLUTANT	AIRCRAFT			NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER		
CARBON MONOXIDE	1.647E+10	1.143E+09	1.887E+10	1.51E+07		2.531E+11
NITROGEN OXIDES	1.856E+08	1.035E+09	2.157E+09	7.57E+07		1.813E+10
SULFUR DIOXIDE	0.8155E+08	4.304E+08	4.237E+07	4.734E+05		5.295E+09
TOTAL PARTICULATES	1.604E+08	6.573E+08	7.318E+07	1.420E+07		4.424E+09
LEAD	1.324E+05	4.447E+04	5.777E+07	0.		NA
TOTAL HYDROCARBONS	5.603E+09	1.205E+09	3.235E+09	1.343E+08		4.389E+10
REACTIVE HYDROCARBONS	NA	NA	NA	NA		NA
ALDEHYDES	1.561E+08	8.533E+07	8.474E+07	7.574E+06		NA

Note: NA indicates data is not available.

TABLE 44 - TOTAL EMISSIONS IN GRAMS AT VAN NUYS AIRPORT AND
SURROUNDINGS FOR THE YEAR 1970

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	1.022E+09	4.991E+08	1.259E+08	0.	9.156E+10
NITROGEN OXIDES	7.458E+06	3.372E+06	1.439E+07	0.	6.194E+09
SULFUR DIOXIDE	4.307E+02	9.802E+02	2.827E+05	0.	1.333E+09
TOTAL PARTICULATES	1.918E+06	1.035E+06	4.883E+05	0.	1.333E+09
LEAD	1.909E+06	9.835E+05	3.855E+05	0.	NA
TOTAL HYDROCARBONS	6.119E+07	3.000E+07	2.159E+07	1.104E+07	1.476E+10
REACTIVE HYDROCARBONS	NA	NA	NA	NA	NA
ALDEHYDES	NA	NA	5.654E+05	NA	NA

Note: NA indicates data is not available.

TABLE 45 - TOTAL EMISSIONS IN GRAMS AT TAMIAHI AIRPORT AND
SURROUNDINGS FOR THE YEAR 1970

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	7.048E+08	3.552E+08	2.851E+07	0.	6.704E+10
NITROGEN OXIDES	5.128E+06	2.339E+06	3.258E+06	0.	4.540E+09
SULFUR DIOXIDE	0.	0.	8.400E+04	0.	1.020E+09
TOTAL PARTICULATES	1.319E+06	7.001E+05	1.105E+05	0.	1.020E+09
LEAD	1.319E+06	7.001E+05	8.722E+04	0.	NA
TOTAL HYDROCARBONS	4.214E+07	2.133E+07	4.887E+06	0.	1.083E+10
REACTIVE HYDROCARBONS	NA	NA	NA	0.	NA
ALDEHYDES	NA	NA	1.280E+05	0.	NA

Note: NA indicates data is not available.

TABLE 46 - AREAL DISTRIBUTION AND EMISSION RATES OF SOURCE POINTS AT WASHINGTON NATIONAL AIRPORT

POINT OF EMISSION

EMISSION RATE, GMS PER SEC

POLLUTANT

NO.	X-COORDINATE	Y-COORDINATE	m	Carbon Monoxide	Nitrogen Oxide	Sulfur Dioxide	Total Particulates	Lead	Total Hydrocarbons	Reactive Hydrocarbons	Aldehydes
AIRCRAFT SPIRALS											
-AT TERMINALS											
1	1.200E+02	3.600E+02		6.132E-01	1.524E-02	9.259E-02	7.421E-02	1.107E-04	8.771E-02	Not Available	4.654E-04
2	1.000E+02	2.000E+02		8.203E-01	2.042E-02	1.252E-02	9.028E-02	1.480E-04	1.173E-01		6.227E-04
3	2.000E+01	1.200E+02		6.132E-01	1.524E-02	9.259E-02	7.421E-02	1.107E-04	8.771E-02		4.654E-04
4	0.000E+01	6.600E+02		2.094E+00	5.218E-02	2.200E-02	2.537E-02	3.783E-04	2.900E-01		1.591E-03
AIRCRAFT SPIRALS											
-ALONG DIKWAYS											
5	1.200E+02	0.000E+02		2.115E-01	8.337E-03	3.820E-02	3.802E-02	4.634E-05	2.907E-02	Not Available	1.764E-04
6	1.000E+02	6.600E+02		5.135E-02	6.104E-03	1.240E-02	2.723E-02	6.273E-04	7.441E-04		2.515E-05
7	2.000E+02	5.044E+02		6.715E-02	5.824E-03	1.288E-02	2.567E-02	5.673E-04	1.012E-02		2.461E-05
8	2.300E+02	3.567E+02		8.212E-02	5.473E-03	1.234E-02	2.414E-02	4.217E-04	1.220E-02		2.430E-05
9	4.000E+02	2.089E+02		7.728E-02	5.089E-03	1.165E-02	2.250E-02	1.411E-04	1.404E-02		2.300E-05
10	4.700E+02	0.111E+01		7.407E-02	4.581E-03	1.070E-02	2.070E-02	0.	1.308E-02		2.135E-05
11	5.400E+02	0.667E+01		5.518E-02	3.944E-03	9.207E-04	1.845E-02	0.	8.676E-04		2.761E-05
12	6.100E+02	2.344E+02		2.246E-02	3.419E-03	7.671E-04	1.612E-02	0.	2.347E-04		2.254E-05
13	6.800E+02	3.822E+02		7.347E-04	3.032E-03	6.651E-04	1.621E-02	0.	1.182E-04		1.909E-05
14	7.500E+02	5.300E+02		2.276E-02	6.874E-03	2.342E-02	6.084E-02	3.680E-04	5.550E-05		9.979E-06
15	8.200E+02	6.822E+02		1.276E-02	2.062E-02	7.027E-02	1.825E-02	1.044E-04	4.604E-02		2.803E-05
16	8.900E+02	8.300E+02		3.827E-02	3.637E-02	1.171E-02	3.042E-02	1.740E-05	7.826E-02		4.821E-04
17	9.600E+02	9.800E+02		5.375E-02	4.812E-02	1.640E-02	4.259E-02	2.434E-05	1.005E-02		6.750E-04
18	1.030E+03	1.130E+03		8.930E-02							

TABLE 46 - AREAL DISTRIBUTION AND EMISSION RATES OF SOURCE POINTS AT WASHINGTON NATIONAL AIRPORT (CONTINUED)

19	-5.940E+03	-1.355E+04	5.153E+02	2.750E+02	9.370E+03	2.434E+02	1.302E+05	6.259E+03	3.857E+04
20	7.500E+02	5.300E+02	1.039E+02	1.518E+02	3.284E+03	6.528E+03	1.218E+05	2.055E+03	8.207E+05
21	1.000E+03	1.075E+03	3.118E+02	4.555E+02	9.854E+03	1.058E+02	3.459E+05	6.166E+03	2.462E+04
22	1.524E+03	2.165E+03	5.196E+02	7.591E+02	1.643E+02	3.264E+02	6.088E+05	1.028E+02	4.103E+04
23	2.290E+03	3.000E+03	7.274E+02	1.063E+01	2.300E+02	6.978E+02	8.523E+05	1.104E+01	5.745E+04
24	3.331E+03	5.580E+03	4.157E+02	6.073E+02	1.314E+02	2.611E+02	4.870E+05	8.221E+03	3.283E+04
25	8.200E+02	1.100E+02	1.905E+02	7.732E+02	3.404E+02	3.604E+02	4.195E+04	2.700E+01	1.600E+03
26	7.080E+02	2.470E+02	5.231E+02	6.007E+02	1.309E+02	2.641E+02	6.104E+05	7.594E+03	3.427E+04
27	5.978E+02	3.856E+02	4.761E+02	5.617E+02	1.244E+02	2.474E+02	5.288E+05	1.036E+02	3.365E+04
28	4.847E+02	5.233E+02	7.842E+02	5.239E+02	1.187E+02	2.313E+02	3.426E+05	1.331E+02	3.310E+04
29	3.756E+02	6.611E+02	7.391E+02	4.791E+02	1.104E+02	2.133E+02	8.422E+04	1.332E+02	3.171E+04
30	2.644E+02	7.585E+02	7.086E+02	4.217E+02	9.922E+03	1.034E+02	0.	1.187E+02	2.954E+04
31	1.533E+02	9.367E+02	3.844E+02	3.590E+02	8.235E+03	1.684E+02	0.	5.948E+03	2.441E+04
32	4.292E+01	1.074E+03	7.514E+03	3.102E+02	6.801E+03	1.455E+02	0.	1.209E+03	1.952E+04
33	-6.880E+01	1.212E+03	4.600E+03	2.722E+02	5.978E+03	1.275E+02	0.	1.041E+03	1.714E+04
34	-1.800E+02	1.350E+03	3.072E+03	1.266E+02	2.783E+03	5.924E+03	0.	4.937E+04	7.978E+05
35	7.080E+02	2.478E+02	1.148E+01	6.187E+02	2.108E+02	5.474E+02	3.132E+05	1.408E+02	8.678E+04
36	1.608E+03	-8.669E+02	3.445E+01	1.854E+01	6.325E+02	1.643E+01	9.395E+05	4.225E+02	2.603E+03
37	3.406E+03	-3.096E+03	5.741E+01	3.093E+01	1.054E+01	2.738E+01	1.566E+04	7.041E+02	4.339E+03
38	6.103E+03	-6.440E+03	8.037E+01	4.331E+01	1.474E+01	3.838E+01	2.192E+04	9.858E+02	6.075E+03
39	0.608E+03	-1.090E+04	4.593E+01	2.475E+01	8.433E+02	2.108E+01	1.253E+04	5.633E+02	3.471E+03
40	-1.800E+02	1.350E+03	9.353E+02	1.366E+01	2.957E+02	5.875E+02	1.094E+04	1.850E+02	7.386E+04
41	-5.555E+02	1.015E+03	2.806E+01	4.099E+01	8.872E+02	1.763E+01	3.288E+04	5.549E+02	2.216E+03
42	-1.314E+03	2.758E+03	4.676E+01	6.832E+01	1.479E+01	2.938E+01	5.470E+04	9.249E+02	3.693E+03
43	-2.451E+03	4.166E+03	6.547E+01	9.564E+01	2.078E+01	6.288E+01	7.671E+04	9.936E+01	5.170E+03
44	-3.045E+03	-6.044E+03	3.741E+01	5.466E+01	1.183E+01	2.350E+01	4.283E+04	7.399E+02	2.954E+03
45	-1.800E+02	1.350E+03	2.117E+00	8.591E+02	3.884E+02	4.004E+02	4.661E+04	3.000E+01	1.778E+03
46	-6.880E+01	1.212E+03	5.812E+02	6.474E+02	1.455E+02	2.935E+02	6.784E+05	8.438E+03	3.808E+04
47	4.222E+01	1.074E+03	7.512E+02	6.241E+02	1.385E+02	2.751E+02	5.974E+05	1.152E+02	3.739E+04
48	1.533E+02	9.367E+02	8.713E+02	5.323E+02	1.319E+02	2.570E+02	3.807E+05	1.457E+02	3.678E+04
49	2.644E+02	7.585E+02	7.873E+02	4.684E+02	1.227E+02	2.371E+02	9.588E+04	1.488E+02	3.524E+04
50	3.756E+02	6.611E+02	7.873E+02	4.684E+02	1.102E+02	2.149E+02	0.	1.319E+02	3.284E+04
51	4.847E+02	5.233E+02	4.271E+02	3.989E+02	9.151E+02	1.873E+02	0.	6.609E+03	2.712E+04
52	5.978E+02	3.856E+02	9.349E+02	3.447E+02	7.554E+03	1.614E+02	0.	1.344E+03	2.169E+04
53	7.080E+02	2.478E+02	7.334E+03	3.025E+02	6.642E+03	1.414E+02	0.	1.179E+03	1.905E+04
54	8.200E+02	1.100E+02	3.413E+03	1.407E+02	3.092E+03	6.582E+03	0.	5.484E+04	8.865E+05
55	-6.880E+01	1.212E+03	1.276E+01	6.874E+02	2.342E+02	6.084E+03	3.380E+05	1.565E+02	9.642E+04

Not
Available

TABLE 46 - AREAL DISTRIBUTION AND EMISSION RATES OF SOURCE POINTS AT WASHINGTON NATIONAL AIRPORT (CONTINUED)

54	-0.478E+02	2.227E+03	3.827E-01	2.042E-01	7.027E-02	1.825E-01	1.044E-04	4.604E-02	2.893E-03
57	-2.746E+03	4.556E+03	6.375E-01	3.437E-01	1.171E-01	3.042E-01	1.740E-04	7.826E-02	4.821E-03
58	-5.463E+03	7.000E+03	8.933E-01	4.812E-01	1.640E-01	4.250E-01	2.434E-04	1.005E-01	6.750E-03
59	-0.058E+03	1.234E+04	5.103E-01	2.750E-01	0.370E-01	2.434E-01	1.392E-04	6.250E-02	3.857E-03
60	8.200E+02	1.100E+02	1.035E-01	1.510E-01	3.294E-02	6.528E-02	1.218E-04	2.055E-02	8.207E-04
61	1.100E+02	-3.504E+02	3.118E-01	4.555E-01	0.858E-02	1.058E-01	3.453E-04	6.146E-02	2.442E-03
62	1.956E+03	-1.298E+03	5.196E-01	7.591E-01	1.642E-01	3.264E-01	6.088E-04	1.028E-01	4.103E-03
63	3.051E+03	-2.706E+03	7.274E-01	1.063E+00	2.300E-01	6.078E-01	8.523E-04	1.104E-00	5.745E-03
64	4.605E+03	-4.584E+03	4.157E-01	6.073E-01	1.314E-01	2.611E-01	4.470E-04	8.221E-02	3.283E-03
65	4.600E+02	-7.800E+02	2.124E+00	9.570E-02	4.007E-02	4.435E-02	4.753E-04	3.011E-01	1.833E-03
66	4.611E+02	-5.511E+02	8.586E-02	8.501E-02	1.865E-02	3.740E-02	8.761E-05	1.255E-02	4.934E-04
67	4.222E+02	-3.222E+02	1.053E-01	7.770E-02	1.744E-02	3.420E-02	5.915E-05	1.712E-02	4.797E-04
68	4.023E+02	-9.333E+01	1.073E-01	6.958E-02	1.601E-02	3.102E-02	1.020E-05	1.804E-02	4.583E-04
69	3.844E+02	1.354E+02	8.517E-02	5.804E-02	1.370E-02	2.708E-02	1.020E-05	1.424E-02	4.051E-04
70	3.654E+02	3.444E+02	3.833E-02	4.430E-02	1.094E-02	2.274E-02	0.	5.801E-02	3.215E-04
71	3.467E+02	5.033E+02	9.799E-03	4.062E-02	0.873E-03	1.893E-02	0.	1.574E-02	2.545E-04
72	3.278E+02	8.222E+02	8.090E-03	3.331E-02	7.333E-03	1.557E-02	0.	1.200E-02	2.101E-04
73	3.059E+02	1.051E+03	3.820E-03	1.570E-02	3.445E-03	7.320E-03	0.	6.120E-04	9.917E-05
74	2.900E+02	1.280E+03	2.020E-04	8.290E-04	1.833E-04	3.861E-04	0.	3.337E-05	0.642E-04
75	4.411E+02	-5.511E+02	1.274E-01	6.874E-02	2.325E-02	6.084E-02	3.480E-05	1.545E-02	9.642E-04
76	5.580E+02	-1.078E+03	3.827E-01	2.062E-01	7.027E-02	1.825E-01	1.044E-04	4.604E-02	2.893E-03
77	7.964E+02	-4.833E+03	4.375E-01	3.437E-01	1.171E-01	3.042E-01	1.740E-04	7.826E-02	4.821E-03
78	1.148E+03	-9.114E+03	5.930E-01	4.812E-01	1.640E-01	4.250E-01	2.434E-04	1.005E-01	6.750E-03
79	1.610E+03	-1.482E+04	5.103E-01	2.750E-01	0.370E-01	2.434E-01	1.392E-04	6.250E-02	3.857E-03
80	3.000E+02	1.280E+03	1.035E-01	1.510E-01	3.294E-02	6.528E-02	1.218E-04	2.055E-02	8.207E-04
81	2.604E+02	1.881E+03	3.118E-01	4.555E-01	0.858E-02	1.058E-01	3.453E-04	6.146E-02	2.442E-03
82	1.417E+02	3.882E+03	5.196E-01	7.591E-01	1.642E-01	3.264E-01	6.088E-04	1.028E-01	4.103E-03
83	-7.561E+00	4.886E+03	7.274E-01	1.063E+00	2.300E-01	6.078E-01	8.523E-04	1.104E-00	5.745E-03
84	-2.050E+02	7.200E+03	4.157E-01	6.073E-01	1.314E-01	2.611E-01	4.470E-04	8.221E-02	3.283E-03
85	2.300E+02	1.280E+03	2.124E+00	9.570E-02	4.007E-02	4.435E-02	4.753E-04	3.011E-01	1.833E-03
86	3.050E+02	1.051E+03	8.586E-02	8.501E-02	1.865E-02	3.740E-02	8.761E-05	1.255E-02	4.934E-04
87	3.278E+02	8.222E+02	1.053E-01	7.770E-02	1.744E-02	3.420E-02	5.915E-05	1.712E-02	4.797E-04
88	3.467E+02	5.033E+02	1.073E-01	6.958E-02	1.601E-02	3.102E-02	1.020E-05	1.804E-02	4.583E-04
89	3.654E+02	3.444E+02	8.517E-02	5.804E-02	1.370E-02	2.708E-02	0.	1.424E-02	4.051E-04
90	3.844E+02	1.354E+02	8.586E-02	8.501E-02	1.865E-02	3.740E-02	0.	5.801E-02	3.215E-04
91	4.023E+02	-9.333E+01	1.073E-01	6.958E-02	1.601E-02	3.102E-02	0.	1.574E-02	2.545E-04
92	4.222E+02	-3.222E+02	1.053E-01	7.770E-02	1.744E-02	3.420E-02	0.	1.200E-02	2.101E-04
93	4.411E+02	-5.511E+02	8.586E-02	8.501E-02	1.865E-02	3.740E-02	0.	6.120E-04	9.917E-05

Not
Available

TABLE 46 -- AREAL DISTRIBUTION AND EMISSION RATES OF SOURCE POINTS AT WASHINGTON NATIONAL AIRPORT (CONTINUED)

94	4.600E+02	-7.800E+02	2.020E+04	8.290E+04	1.833E+04	3.861E+04	0.480E+05	3.277E+05	5.242E-04
95	2.050E+02	1.051E+03	1.276E+01	6.874E+02	2.342E+02	6.084E+02	1.545E+02	1.545E+02	9.642E-04
96	1.011E+02	2.478E+03	3.827E+01	2.062E+01	7.027E+02	1.825E+01	1.044E+04	4.694E+02	2.893E-03
97	-4.643E+01	5.733E+03	6.375E+01	3.437E+01	1.171E+01	3.042E+01	1.740E+04	7.824E+02	4.821E-03
98	-2.978E+02	9.614E+03	8.930E+01	4.812E+01	1.640E+01	4.250E+01	2.434E+04	1.095E+01	6.780E-03
99	-0.680E+02	1.532E+04	5.103E+01	2.750E+01	9.770E+02	2.434E+01	1.392E+04	4.250E+02	3.857E-03
100	4.600E+02	-7.800E+02	1.039E+01	1.518E+01	3.284E+02	6.528E+02	1.318E+04	2.055E+02	8.207E-04
101	5.064E+02	-1.381E+03	3.118E+01	4.555E+01	9.858E+02	1.958E+01	3.653E+04	6.166E+02	2.462E-03
102	4.088E+02	-2.583E+03	5.196E+01	7.591E+01	1.643E+01	3.264E+01	6.088E+04	1.028E+01	4.103E-03
103	7.574E+02	-4.384E+03	7.274E+01	1.063E+00	2.300E+01	6.978E+01	8.223E+04	1.104E+00	5.745E-03
104	9.550E+02	-6.790E+03	4.157E+01	6.073E+01	1.314E+01	2.611E+01	4.870E+04	8.221E+02	3.283E-03

Not
Available

TERRESTRIAL SOURCE
-ALONG TAXIWAYS

105	2.500E+02	-2.800E+02	1.682E+00	4.135E+02	2.524E+02	2.003E+02	3.451E+04	2.384E+01	1.275E-03
106	2.450E+02	1.100E+02	3.364E+00	8.269E+02	5.048E+02	4.005E+02	6.003E+04	4.768E+01	2.551E-03
107	2.400E+02	5.000E+02	3.364E+00	8.269E+02	5.048E+02	4.005E+02	6.003E+04	4.768E+01	2.551E-03
108	2.350E+02	8.500E+02	3.364E+00	8.269E+02	5.048E+02	4.005E+02	6.003E+04	4.768E+01	2.551E-03
109	2.300E+02	1.280E+03	1.682E+00	4.135E+02	2.524E+02	2.003E+02	3.451E+04	2.384E+01	1.275E-03
110	2.250E+02	-1.000E+02	1.598E+00	3.928E+02	2.398E+02	1.003E+02	3.270E+04	2.265E+01	1.212E-03
111	2.200E+02	-1.075E+02	3.196E+00	7.856E+02	4.796E+02	3.805E+02	6.557E+04	4.530E+01	2.423E-03
112	5.280E+01	-3.500E+01	3.196E+00	7.856E+02	4.796E+02	3.805E+02	6.557E+04	4.530E+01	2.423E-03
113	4.775E+02	3.750E+01	3.196E+00	7.856E+02	4.796E+02	3.805E+02	6.557E+04	4.530E+01	2.423E-03
114	8.200E+02	1.100E+02	1.598E+00	3.928E+02	2.398E+02	1.003E+02	3.270E+04	2.265E+01	2.423E-03
115	2.500E+02	-2.800E+02	8.410E+00	2.067E+02	1.262E+02	1.001E+02	1.726E+05	1.192E+02	1.212E-03
116	2.025E+02	-3.055E+02	1.682E+01	4.135E+03	2.524E+02	2.003E+02	3.451E+05	2.384E+02	6.376E-05
117	1.550E+02	-5.100E+02	1.682E+01	4.135E+03	2.524E+02	2.003E+02	3.451E+05	2.384E+02	1.275E-04
118	1.075E+02	-6.250E+02	1.682E+01	4.135E+03	2.524E+02	2.003E+02	3.451E+05	2.384E+02	1.275E-04
119	6.000E+01	-7.100E+02	8.410E+00	2.067E+02	1.262E+02	1.001E+02	1.726E+05	1.192E+02	6.376E-05

Not
Available

TABLE 46 - AREAL DISTRIBUTION AND EMISSION RATES OF SOURCE POINTS AT WASHINGTON NATIONAL AIRPORT (CONTINUED)

[illegible]

TABLE 46 - AREAL DISTRIBUTION AND EMISSION RATES OF SOURCE POINTS AT WASHINGTON NATIONAL AIRPORT (CONTINUED)

SLURRYING SOURCE POINTS

135	-1.420F+03	-3.710F+03	2.521F+02	1.814F+01	4.775F+00	3.820F+00	0.	4.488F+01	0.
136	-3.140F+03	-1.640F+03	1.938F+02	1.395F+01	3.670F+00	2.034F+00	0.	3.450F+01	0.
137	-2.820F+03	7.850F+02	2.772F+02	1.995F+01	5.250F+00	4.200F+00	0.	4.935F+01	0.
138	-1.920F+03	2.750F+03	4.925F+02	3.523F+01	1.409F+01	1.253F+01	0.	7.987F+01	0.
139	1.710F+03	3.600F+03	2.244F+02	1.615F+01	4.250F+00	3.400F+00	0.	3.995F+01	0.
140	3.530F+03	2.860F+02	9.636F+01	6.424F+00	1.604F+00	8.030F+01	0.	1.526F+01	0.
141	2.870F+03	-2.250F+03	8.904F+01	5.934F+00	1.484F+00	7.420F+01	0.	1.410F+01	0.
142	-2.820F+03	-6.850F+03	3.091F+02	2.090F+01	4.400F+00	4.400F+00	0.	4.977F+01	0.
143	-6.900F+03	-2.780F+03	2.316F+02	2.242F+01	4.720F+00	4.720F+00	0.	5.330F+01	0.
144	-6.900F+03	2.880F+03	7.788F+02	5.605F+01	1.475F+01	1.180F+01	0.	1.386F+02	0.
145	-2.890F+03	6.500F+03	7.788F+02	5.605F+01	1.475F+01	1.180F+01	0.	1.386F+02	0.
146	2.890F+03	6.500F+03	2.105F+02	1.741F+02	2.004F+02	1.268F+02	0.	3.451F+02	0.
147	6.900F+03	2.880F+03	2.105F+02	1.741F+02	2.004F+02	1.268F+02	0.	3.451F+02	0.
148	6.900F+03	-2.780F+03	7.788F+02	5.605F+01	1.475F+01	1.180F+01	0.	1.386F+02	0.
149	4.100F+03	-7.140F+03	2.214F+02	1.497F+01	3.152F+00	3.152F+00	0.	3.566F+01	0.

Not
Available

TABLE 47 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS FOR PEAK MONTH (JUNE) OF YEAR

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	1.226E+08	2.613E+07	1.130E+08	4.095E+03	2.344E+10
NITROGEN OXIDES	4.443E+06	2.508E+07	9.456E+06	1.032E+07	1.789E+09
SULFUR DIOXIDE	2.229E+06	6.235E+06	2.537E+05	1.540E+07	1.277E+09
TOTAL PARTICULATES	2.617E+06	1.371E+07	4.382E+05	8.191E+05	8.548E+08
LEAD	2.603E+04	1.642E+04	3.459E+05	0.	NA
TOTAL HYDROCARBONS	1.732E+07	1.485E+07	1.937E+07	4.914E+05	3.948E+09
ALDEHYDES	1.047E+05	1.935E+05	5.074E+05	8.191E+04	NA

Note: NA indicates data is not available.

TABLE 48 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS
FOR LOW MONTH (FEBRUARY) OF YEAR

POLLUTANT	AIRCRAFT			NON-AIRCRAFT			AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER			
CARBON MONOXIDE	9.989E+07	2.129E+07	9.206E+07	3.822E+03			2.188E+10
NITROGEN OXIDES	3.619E+06	2.043E+07	7.703E+06	9.632E+06			1.670E+09
SULFUR DIOXIDE	1.816E+06	5.079E+06	2.067E+05	1.437E+07			1.192E+09
TOTAL PARTICULATES	2.132E+06	1.117E+07	3.570E+05	7.645E+05			7.979E+08
LEAD	2.121E+04	1.337E+04	2.818E+05	0.			NA
TOTAL HYDROCARBONS	1.411E+07	1.209E+07	1.578E+07	4.587E+05			3.684E+09
ALDEHYDES	8.533E+04	1.576E+05	4.133E+05	7.645E+04			NA

Note: NA indicates data is not available.

TABLE 49 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS
FOR PEAK DAY (FRIDAY) OF WEEK

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	3.974E+06	8.464E+05	3.669E+06	1.365E+02	7.813E+08
NITROGEN OXIDES	1.444E+05	8.140E+05	3.070E+05	3.440E+05	5.964E+07
SULFUR DIOXIDE	7.233E+04	2.023E+05	8.236E+03	5.133E+05	4.258E+07
TOTAL PARTICULATES	8.493E+04	4.449E+05	1.423E+04	2.730E+04	2.849E+07
LEAD	8.407E+02	5.301E+02	1.123E+04	0.	NA
TOTAL HYDROCARBONS	5.618E+05	4.823E+05	6.290E+05	1.638E+04	1.316E+08
ALDEHYDES	3.371E+03	6.276E+03	1.647E+04	2.730E+03	NA

Note: NA indicates data is not available.

TABLE 50 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS
FOR LOW DAY (SATURDAY) OF WEEK

POLLUTANT	AIRCRAFT		NON-AIRCRAFT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	2.689E+06	5.729E+05	2.485E+06	1.365E+02	7.813E+08
NITROGEN OXIDES	9.818E+04	5.510E+05	2.080E+05	3.440E+05	5.964E+07
SULFUR DIOXIDE	4.898E+04	1.369E+05	5.579E+03	5.133E+05	4.258E+07
TOTAL PARTICULATES	5.746E+04	3.008E+05	9.637E+03	2.730E+04	2.849E+07
LEAD	5.697E+02	3.592E+02	7.608E+03	0.	NA
TOTAL HYDROCARBONS	3.805E+05	3.275E+05	4.261E+05	1.638E+04	1.316E+08
ALDEHYDES	2.275E+03	4.241E+03	1.116E+04	2.730E+03	NA

Note: NA indicates data is not available.

TABLE 51 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS
FOR MORNING HOUR (8 AM, WINTER)

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	3.205E+05	6.790E+04	2.972E+05	5.688E+00	3.255E+07
NITROGEN OXIDES	1.142E+04	6.612E+04	2.487E+04	1.433E+04	2.485E+06
SULFUR DIOXIDE	5.838E+03	1.644E+04	6.671E+02	2.139E+04	1.774E+06
TOTAL PARTICULATES	6.929E+03	3.639E+04	1.152E+03	1.138E+03	1.187E+06
LEAD	6.637E+01	4.185E+01	9.095E+02	0.	NA
TOTAL HYDROCARBONS	4.517E+04	3.851E+04	5.094E+04	6.826E+02	5.483E+06
ALDEHYDES	2.542E+02	5.148E+02	1.334E+03	1.138E+02	NA

Note: NA indicates data is not available.

TABLE 52 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND SURROUNDINGS
FOR NOON HOUR (WINTER)

POLLUTANT	AIRCRAFT		NON-AIRCRAFT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	2.530E+05	5.431E+04	2.352E+05	5.688E+00	3.255E+07
NITROGEN OXIDES	9.303E+03	5.205E+04	1.968E+04	1.433E+04	2.485E+06
SULFUR DIOXIDE	4.614E+03	1.292E+04	5.280E+02	2.139E+04	1.774E+06
TOTAL PARTICULATES	5.434E+03	2.842E+04	9.120E+02	1.138E+03	1.187E+06
LEAD	5.531E+01	3.487E+01	7.200E+02	0	NA
TOTAL HYDROCARBONS	3.582E+04	3.105E+04	4.032E+04	6.826E+02	5.483E+06
ALDEHYDES	1.977E+02	4.004E+02	1.056E+03	1.138E+02	NA

Note: NA indicates data is not available.

TABLE 53 - TOTAL EMISSIONS IN GRAMS AT WASHINGTON NATIONAL AIRPORT AND
SURROUNDINGS FOR EVENING HOUR (6 PM, WINTER)

POLLUTANT	AIRCRAFT		NON-AIRCRAFT AIRPORT		AIRPORT SURROUNDINGS
	GROUND OPERATIONS	FLIGHT OPERATIONS	AUTO TRAVEL	OTHER	
CARBON MONOXIDE	2.883E+05	6.139E+04	2.698E+05	5.688E+00	3.255E+07
NITROGEN OXIDES	1.073E+04	5.965E+04	2.257E+04	1.433E+04	2.485E+06
SULFUR DIOXIDE	5.292E+03	1.480E+04	6.056E+02	2.139E+04	1.774E+06
TOTAL PARTICULATES	6.222E+03	3.251E+04	1.046E+03	1.138E+03	1.187E+06
LEAD	6.084E+01	3.836E+01	8.258E+02	0.	NA
TOTAL HYDROCARBONS	4.101E+04	3.570E+04	4.625E+04	6.826E+02	5.483E+06
ALDEHYDES	2.260E+02	4.576E+02	1.211E+03	1.138E+02	NA

Note: NA indicates data is not available.

TABLE 54 - AIRCRAFT EMISSIONS BY OPERATIONAL MODE AT
WASHINGTON NATIONAL AIRPORT FOR THE YEAR 1970

Operational Mode	Pollutant, gms x 10 ⁻⁶							
	Carbon Monoxide	Nitrogen Oxide	Sulfur Dioxide	Particulates	Lead	Total Hydrocarbons	Reactive Hydrocarbons	Aldehydes
Approach	130	69	24	61	0.035	16		0.97
Landing	35	0.87	0.53	0.42	0.0073	5.0		0.027
Taxi	850	21	13	10	0.17	120		0.64
Idle and Shutdown	24	0.64	0.40	0.32	0.0018	3.6		0.019
Maintenance	140	20	6.4	15	0.041	19	Not Available	0.23
Start-up and Idle	110	2.6	1.6	1.3	0.022	15		0.080
Idle at Runway	260	6.5	4.0	3.1	0.054	37		0.20
Take-off	25	59	13	27	0.019	4.8		0.35
Climb-out	100	150	33	66	0.12	21		0.83
Fuel Venting	0	0	0	0	0	120		0
Operational Cycle*	1700	330	95	180	0.48	360		3.4

* The operational cycle comprises modes 1 through 10.

TABLE 55 - AIR QUALITY STANDARDS
TAKEN FROM THE FEDERAL REGISTER

<u>Carbon Monoxide</u> (Primary and Secondary)	a) 10 milligrams per cubic meter (9 ppm), maximum 8-hour concentration not to be exceeded more than once per year. b) 40 milligrams per cubic meter (35 ppm), maximum 1-hour concentration not to be exceeded more than once per year.
<u>Nitrogen Dioxide</u> (Primary and Secondary)	a) 100 micrograms per cubic meter (0.05 ppm), annual arithmetic mean.
<u>Non-methane Hydrocarbons</u> (Primary and Secondary)	For use as a guide in devising implementation plans to achieve oxidant standards. a) 160 micrograms per cubic meter (0.24 ppm), maximum 3-hour concentration (6-9 am) not to be exceeded more than once per year.
<u>Particulate Matter</u> (Primary)	a) 75 micrograms per cubic meter, annual geometric mean. b) 260 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year.
<u>Particulate Matter</u> (Secondary)	a) 60 micrograms per cubic meter, annual geometric mean, as a guide to be used in assessing implementation plans to achieve the 24-hour standard. b) 150 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year.
<u>Sulfur Dioxide</u> (Primary)	a) 80 micrograms per cubic meter (0.03 ppm), annual arithmetic mean. b) 365 micrograms per cubic meter (0.14 ppm), maximum 24-hour concentration not to be exceeded more than once per year.

TABLE 55 - AIR QUALITY STANDARDS TAKEN FROM
THE FEDERAL REGISTER (CONTINUED)

<u>Sulfur Dioxide</u> (Secondary)	a) 60 micrograms per cubic meter (0.02 ppm), annual arithmetic mean. b) 260 micrograms per cubic meter (0.1 ppm), maximum 24-hour concentration not to be exceeded more than once per year, as a guide to be used in assessing implementation plans to achieve the annual standard. c) 1,300 micrograms per cubic meter (0.5 ppm), maximum 3-hour concentration not to be exceeded more than once per year.
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TABLE 56 - CONCENTRATION OUTPUT FOR A SAMPLE RECEPTOR

RECEPTOR POINT NO. 1 (X = 1.200E + 02 M, Y = 3.600E + 02 M, Z = 2.000E + 00 M)

AVERAGE CONCENTRATION IN TIME PERIOD, GMS PER CU M

POLLUTANT	AIRCRAFT	SOURCE NON-AIRCRAFT AIRPORT	SURROUNDINGS
CARBON MONOXIDE	3.497E-04	1.965E-04	5.953E-04
NITROGEN OXIDES	1.432E-05	3.215E-05	4.388E-05
SULFUR DIOXIDE	5.351E-06	1.490E-05	2.254E-05
TOTAL PARTICULATES	7.265E-06	1.531E-06	1.612E-05
LEAD	4.384E-08	7.621E-07	0.
TOTAL HYDROCARBONS	7.430E-05	3.415E-05	1.009E-04
REACTIVE HYDROCARBONS	NA	NA	NA
ALDEHYDES	2.170E-06	9.593E-07	0.

Note: NA indicates data is not available.

**TABLE 57 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
WASHINGTON NATIONAL AIRPORT**

Receptor Points (See Figs 21 and 22)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	9.4	27	17	93	6.7	44	0.0	0.8
2	7.1	24	13	86	4.9	44	0.0	0.7
3	5.9	24	10	110	3.0	56	0.0	1.2
4	8.9	30	14	142	4.6	66	0.0	1.9
5	11	35	22	100	6.9	53	0.0	0.5
6	18	33	36	80	14	40	0.0	0.2
7	9.5	26	18	68	6.1	33	0.0	0.2
8	3.9	19	6.8	59	2.4	31	0.0	0.2
9	35	52	71	120	25	58	0.2	0.4
10	12	27	24	68	8.3	32	0.0	0.2
11*	41	58	83	140	25	64	0.2	0.5
12*	67	84	140	190	46	79	0.2	0.5
13	9.0	30	17	82	5.1	43	0.0	0.3
14	9.4	26	18	68	5.8	34	0.0	0.2
15	8.1	25	16	65	5.1	33	0.0	0.2
16	9.0	25	18	66	6.4	34	0.0	0.1
17	9.8	25	19	62	7.2	33	0.0	0.1
18	5.4	19	10	50	3.7	26	0.0	0.1
19	5.2	19	9.6	50	3.4	27	0.0	0.1
20	2.2	18	4.0	50	1.4	29	0.0	0.1
21	1.8	16	3.0	51	0.9	25	0.0	0.1
22	2.2	17	3.7	58	1.3	28	0.0	0.1
23	3.1	19	4.9	60	1.5	30	0.0	0.2
24	3.9	22	6.1	81	2.0	48	0.0	0.5
25	5.2	25	8.2	120	2.5	87	0.0	1.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

* Invalid receptor locations.

TABLE 57 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
WASHINGTON NATIONAL AIRPORT (CONTINUED)

Receptor Points (See Figs 21 and 22)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	3.9	25	6.4	110	2.0	83	0.0	0.7
27	5.0	34	8.2	210	2.6	220	0.0	0.9
28	10	32	16	130	4.5	65	0.0	1.5
29	1.7	19	2.9	63	0.9	33	0.0	0.2
30	0.9	32	1.7	86	0.5	44	0.0	0.1
31	1.4	21	2.4	52	0.7	31	0.0	0.0
32	1.3	45	2.3	120	0.6	65	0.0	0.0
33	1.0	46	1.8	85	0.5	70	0.0	0.0
34	0.9	40	1.4	72	0.4	61	0.0	0.0
35	0.8	30	1.3	61	0.4	47	0.0	0.0
36	0.6	18	1.0	44	0.2	27	0.0	0.0
37	0.6	16	1.2	45	0.4	23	0.0	0.0
38	0.8	12	1.3	31	0.4	18	0.0	0.0
39	0.5	12	0.8	35	0.2	18	0.0	0.0
40	0.4	14	0.7	47	0.2	19	0.0	0.0
41	0.4	11	0.7	36	0.2	15	0.0	0.0
42	0.4	13	0.6	42	0.1	18	0.0	0.0
43	0.4	14	0.6	43	0.2	19	0.0	0.0
44	0.4	13	0.6	36	0.1	17	0.0	0.0
45	0.4	17	0.7	52	0.2	24	0.0	0.0
46	0.5	36	1.0	100	0.2	46	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

**TABLE 58 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
J. F. KENNEDY INTERNATIONAL AIRPORT**

Receptor Points (See Figs 23 and 24)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	10	18	11	140	7.9	34	0.0	3.1
2	7.0	17	7.9	190	5.8	45	0.0	4.7
3	6.5	19	7.7	220	5.3	78	0.0	5.2
4	6.9	19	8.4	210	5.8	58	0.0	5.3
5	8.7	17	10	150	7.4	28	0.0	3.7
6	5.7	14	6.9	140	4.9	31	0.0	3.4
7	5.3	14	6.6	140	4.8	36	0.0	3.4
8	6.4	15	7.4	140	5.8	28	0.0	3.7
9	11	19	11	130	9.0	29	0.0	3.0
10	7.6	16	9.5	130	7.4	24	0.0	3.1
11	9.6	18	16	110	9.5	21	0.0	2.5
12	11	15	18	55	9.5	20	0.0	0.4
13	6.0	13	8.9	52	4.1	14	0.0	0.6
14	27	31	40	67	19	26	0.0	0.3
15	2.0	7.6	3.2	32	1.9	11	0.0	0.3
16	14	20	21	68	11	24	0.0	0.6
17	7.6	12	12	37	7.4	14	0.0	0.2
18	10	16	18	55	12	22	0.0	0.3
19	7.6	16	11	120	7.9	35	0.0	0.5
20	3.3	10	5.1	58	2.8	17	0.0	0.8
21	3.9	11	6.2	58	3.3	17	0.0	0.7
22	4.1	11	6.4	50	3.7	17	0.0	2.5
23	2.8	9.6	4.6	42	2.7	13	0.0	0.3
24	2.1	8.1	3.5	35	2.0	10	0.0	0.2
25	3.8	8.8	6.6	34	3.6	11	0.0	0.3
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

TABLE 58 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
J. F. KENNEDY INTERNATIONAL AIRPORT (CONTINUED)

Receptor Points (See Figs 23 and 24)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total	Air-craft	Total
26	4.2	9.3	6.7	33	3.9	12	0.0	0.2
27	3.7	9.0	6.8	35	4.1	13	0.0	0.3
28	4.0	10	6.5	47	4.3	16	0.0	0.6
29	3.7	9.3	5.5	49	4.0	14	0.0	0.7
30	3.8	9.6	6.3	52	4.3	14	0.0	0.8
31	2.9	9.9	4.6	47	2.3	12	0.0	0.6
32	0.8	18	1.3	85	0.6	22	0.0	0.2
33	1.6	10	2.6	85	1.3	12	0.0	1.8
34	1.8	9.5	2.8	74	1.5	12	0.0	1.5
35	1.2	7.5	1.9	38	1.1	10	0.0	0.3
36	1.1	8.0	1.9	38	1.0	10	0.0	0.2
37	1.1	8.2	1.7	39	0.9	10	0.0	0.2
38	1.1	7.8	1.8	37	1.0	10	0.0	0.2
39	1.2	5.8	1.9	26	1.1	7.6	0.0	0.1
40	1.0	5.1	1.6	21	0.8	6.1	0.0	0.1
41	0.9	5.9	1.5	25	0.8	7.1	0.0	0.1
42	1.0	6.7	1.7	27	0.8	7.2	0.0	0.1
43	0.9	7.2	1.5	26	0.8	8.7	0.0	0.1
44	0.9	21	1.5	63	0.8	23	0.0	0.1
45	0.9	28	1.5	83	0.8	31	0.0	0.1
46	1.0	4.8	1.6	21	0.8	6.1	0.0	0.1
47	0.9	4.6	1.5	22	0.8	6.2	0.0	0.2
48	0.6	9.5	1.1	44	0.5	13	0.0	0.2
49	0.6	9.0	1.1	41	0.5	12	0.0	0.1
50	0.9	7.8	1.6	37	0.8	9	0.0	0.2
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

**TABLE 59 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT LOS ANGELES
INTERNATIONAL AIRPORT**

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	12	21	17	120	9.7	22	0.0	2.6
2	13	23	17	150	9.7	24	0.0	3.5
3	13	21	18	110	11	22	0.0	2.3
4	15	23	16	130	9.7	25	0.0	3.0
5	17	27	19	160	12	24	0.0	3.6
6	15	24	17	130	11	22	0.0	2.8
7	11	18	22	66	14	21	0.0	0.5
8	38	46	64	130	25	34	0.0	1.3
9	25	33	60	110	37	46	0.0	0.6
10	86	93	140	220	55	65	0.1	1.8
11	6.2	15	11	64	5.9	16	0.0	0.7
12	120	130	210	280	81	91	0.1	0.9
13	5.1	14	8.7	61	4.7	16	0.0	0.6
14	97	110	170	230	64	74	0.1	0.6
15	8.6	16	15	68	7.6	18	0.0	0.8
16	8.3	17	14	89	6.8	17	0.0	1.5
17	3.9	15	6.8	74	3.3	16	0.0	0.6
18	5.6	16	9.4	91	4.7	16	0.0	1.5
19	7.3	18	13	120	6.8	19	0.0	2.2
20	6.1	18	11	82	5.5	21	0.0	0.5
21	4.1	15	7.8	74	4.2	17	0.0	0.7
22	4.3	16	7.8	130	4.7	18	0.0	2.7
23	4.6	13	8.1	63	5.1	16	0.0	0.7
24	5.2	12	9.5	55	5.9	15	0.0	0.5
25	3.8	14	6.4	64	3.4	15	0.0	0.4
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

**TABLE 59 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT LOS ANGELES
INTERNATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	3.3	10	5.7	47	2.8	12	0.0	0.4
27	4.5	12	7.9	51	3.5	12	0.0	0.5
28	5.3	13	9.7	54	5.5	16	0.0	0.5
29	6.3	13	12	57	6.4	15	0.0	0.5
30	3.2	12	5.6	53	2.9	14	0.0	0.3
31*	280	290	470	540	170	180	0.2	1.1
32*	490	500	830	900	280	290	0.4	1.2
33	1.2	10	2.1	38	1.0	11	0.0	0.1
34	1.3	10	2.3	39	1.0	12	0.0	0.1
35	1.6	14	2.9	63	1.4	17	0.0	0.1
36	2.5	15	4.4	66	2.1	17	0.0	0.3
37	3.4	10	6.0	48	2.9	11	0.0	0.4
38	1.8	10	3.2	45	1.6	12	0.0	0.1
39	1.3	13	2.3	57	1.0	15	0.0	0.1
40	1.1	7.4	1.9	32	0.8	9	0.0	0.1
41	1.1	6.7	2.0	30	0.9	7.8	0.0	0.1
42	1.2	7.4	2.2	30	1.1	8.5	0.0	0.1
43	1.4	7.9	2.5	32	1.3	9	0.0	0.1
44	1.6	8.1	2.9	33	1.4	9	0.0	0.1
45	2.5	8.9	4.5	37	2.2	10	0.0	0.3
46	1.8	15	3.1	54	1.5	16	0.0	0.1
47	1.3	30	2.4	99	1.1	35	0.0	0.1
48	1.2	13	2.1	46	1.0	15	0.0	0.1
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

* Invalid receptor locations.

**TABLE 60 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
CHICAGO-O'HARE INTERNATIONAL AIRPORT**

Receptor Points (See Figs 27 and 28)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	16	38	22	380	12	29	0.0	11
2	17	36	23	330	12	29	0.0	8.7
3	15	30	23	220	12	26	0.0	5.2
4	16	29	22	190	12	25	0.0	4.2
5	18	32	24	220	12	25	0.0	5.4
6	26	37	41	130	19	31	0.0	1.6
7	27	44	49	180	22	41	0.0	2.2
8	7.5	22	13	97	6.2	24	0.0	0.6
9	17	37	29	170	12	34	0.0	2.4
10	26	37	42	110	19	31	0.0	1.0
11	65	86	130	450	62	80	0.0	9.0
12	14	25	24	89	11	24	0.0	0.5
13	72	91	120	270	54	75	0.0	2.6
14	29	45	53	140	25	45	0.0	0.6
15	53	91	86	830	36	62	0.0	23
16	25	37	45	110	19	33	0.0	0.4
17	37	49	66	160	29	42	0.0	1.5
18	9.1	25	15	120	7.3	26	0.0	1.3
19	19	35	32	160	14	32	0.0	2.3
20	7.9	26	13	140	5.7	25	0.0	2.1
21	11	32	18	270	7.7	29	0.0	6.5
22	8.9	30	14	240	6.2	28	0.0	5.3
23	14	33	23	160	10	32	0.0	2.1
24	4.1	22	6.9	100	3.2	25	0.0	0.6
25	3.3	35	5.7	160	2.7	41	0.0	0.5
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

TABLE 60 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
CHICAGO-O'HARE INTERNATIONAL AIRPORT (CONTINUED)

Receptor Points (See Figs 27 and 28)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	3.1	20	5.2	97	2.5	23	0.0	0.5
27	3.3	17	5.4	84	2.5	19	0.0	0.5
28	2.1	14	3.5	68	1.6	15	0.0	0.3
29	2.0	14	3.4	63	1.5	15	0.0	0.2
30	2.5	12	4.2	53	1.8	12	0.0	0.3
31	3.4	17	5.6	77	2.5	17	0.0	0.4
32	5.5	17	9.1	70	3.7	17	0.0	0.4
33	16	27	26	93	11	24	0.0	0.7
34	3.4	18	5.6	88	2.6	20	0.0	0.7
35	3.0	26	5.1	130	2.2	30	0.0	0.7
36	2.8	27	4.7	130	2.1	31	0.0	0.6
37	3.2	29	5.3	140	2.3	33	0.0	0.8
38	3.6	26	5.9	130	2.6	28	0.0	1.2
39	3.1	28	5.1	130	2.2	31	0.0	0.8
40	1.8	23	3.0	100	1.4	27	0.0	0.3
41	1.3	17	2.1	73	0.9	19	0.0	0.2
42	1.5	14	2.5	67	1.2	16	0.0	0.3
43	1.3	16	2.1	73	0.9	19	0.0	0.2
44	1.0	12	1.7	56	0.8	14	0.0	0.2
45	0.8	6.5	1.4	30	0.6	7.3	0.0	0.1
46	0.8	5.9	1.4	27	0.6	6.6	0.0	0.1
47	1.2	7.8	1.9	37	0.8	8.6	0.0	0.2
48	1.6	11	2.7	51	1.2	12	0.0	0.2
49	2.6	14	4.3	63	1.8	15	0.0	0.3
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

**TABLE 61 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
VAN NUYS AIRPORT**

Receptor Points (See Figs 29 and 30)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total	Air-craft	Total
1	1.9	7.8	7.4	35	0.0	5.8	1.9	1.9
2	1.0	7.2	4.0	34	0.0	6.1	1.0	1.1
3	1.2	7.0	4.6	32	0.0	5.8	1.2	1.2
4	1.0	6.2	3.8	31	0.0	5.1	1.0	1.1
5	0.4	6.1	1.6	29	0.0	5.7	0.4	0.4
6	0.5	5.7	2.0	27	0.0	5.2	0.5	0.5
7	0.1	6.5	0.5	31	0.0	6.4	0.1	0.1
8	0.4	5.8	1.6	34	0.0	5.3	0.4	0.7
9	0.2	6.7	0.9	39	0.0	6.2	0.2	0.5
10	0.1	7.8	0.4	38	0.0	7.7	0.1	0.2
11	0.3	6.3	1.1	35	0.0	6.0	0.3	0.5
12	0.4	6.0	1.6	42	0.0	5.4	0.4	1.0
13	0.4	5.6	1.5	28	0.0	5.0	0.4	0.5
14	0.1	6.7	0.4	32	0.0	6.5	0.1	0.1
15	0.1	7.0	0.5	34	0.0	6.9	0.1	0.2
16	0.5	6.4	1.8	31	0.0	5.8	0.5	0.6
17	0.0	6.2	0.1	29	0.0	6.2	0.0	0.0
18	0.0	6.0	0.0	28	0.0	6.0	0.0	0.0
19	0.0	9.2	0.0	43	0.0	9.2	0.0	0.0
20	0.0	5.6	0.0	26	0.0	5.6	0.0	0.0
21	0.0	5.8	0.0	27	0.0	5.8	0.0	0.0
22	0.0	6.8	0.0	32	0.0	6.8	0.0	0.0
23	0.0	7.3	0.1	33	0.0	7.3	0.0	0.0
24	0.0	5.9	0.1	26	0.0	6.0	0.0	0.0
25	0.0	4.0	0.9	18	0.0	4.0	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

**TABLE 61 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT
VAN NUYS AIRPORT (CONTINUED)**

Receptor Points (See Figs 29 and 30)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.0	4.2	0.0	19	0.0	4.2	0.0	0.0
27	0.0	7.1	0.0	32	0.0	7.1	0.0	0.0
28	0.0	4.7	0.0	21	0.0	4.7	0.0	0.0
29	0.0	5.5	0.0	25	0.0	5.5	0.0	0.0
30	0.0	7.1	0.1	34	0.0	7.1	0.0	0.0
31	0.0	9.1	0.1	43	0.0	9.1	0.0	0.0
32	0.0	9.3	0.1	44	0.0	9.3	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

TABLE 62 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT TAMIAHI AIRPORT

Receptor Points (See Figs 31 and 32)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total	Air-craft	Total
1	0.5	2.7	1.9	11	0.0	2.2	0.5	0.5
2	0.2	2.4	0.9	9.8	0.0	2.2	0.2	0.2
3	0.5	2.8	1.7	14	0.0	2.4	0.5	0.6
4	0.3	2.9	0.9	15	0.0	2.6	0.3	0.4
5	0.6	2.8	2.1	11	0.0	2.2	0.6	0.6
6	0.3	2.6	1.0	11	0.0	2.3	0.3	0.3
7	0.5	2.6	1.7	11	0.0	2.1	0.5	0.5
8	0.1	2.2	0.5	9.1	0.0	2.1	0.1	0.1
9	0.4	2.6	1.4	10	0.0	2.2	0.4	0.4
10	0.2	2.4	0.9	10	0.0	2.2	0.2	0.3
11	0.4	2.6	1.4	10	0.0	2.2	0.4	0.4
12	0.4	2.9	1.6	12	0.0	2.5	0.4	0.4
13	0.2	2.4	0.8	9.3	0.0	2.1	0.2	0.2
14	0.6	2.9	2.3	12	0.0	2.3	0.6	0.6
15	0.2	2.4	0.6	9.6	0.0	2.2	0.2	0.2
16	0.1	2.3	0.5	9.7	0.0	2.2	0.1	0.2
17	0.1	2.3	0.4	9.6	0.0	2.2	0.1	0.1
18	0.0	3.1	0.1	11	0.0	2.6	0.0	0.0
19	0.1	3.0	0.2	13	0.0	3.0	0.1	0.1
20	0.1	3.4	0.2	14	0.0	3.3	0.1	0.1
21	0.2	2.7	0.8	12	0.0	2.5	0.2	0.2
22	0.2	2.5	0.8	11	0.0	2.3	0.2	0.2
23	0.2	2.5	0.6	10	0.0	2.3	0.2	0.2
24	0.1	2.4	0.5	9.9	0.0	2.3	0.1	0.1
25	0.1	2.4	0.2	9.2	0.0	2.3	0.1	0.1
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

TABLE 62 - 1970 ANNUAL AVERAGE CONCENTRATIONS AT TAMiami AIRPORT
(CONTINUED)

Receptor Points (See Figs 31 and 32)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.0	2.3	0.1	9.4	0.0	2.3	0.0	0.0
27	0.1	2.5	0.3	9.7	0.0	2.4	0.1	0.1
28	0.1	2.4	0.3	9.0	0.0	2.2	0.1	0.1
29	0.2	2.4	0.6	9.5	0.0	2.2	0.2	0.2
30	0.2	2.4	0.6	9.3	0.0	2.2	0.2	0.2
31	0.0	2.1	0.0	8.3	0.0	2.1	0.0	0.0
32	0.0	3.0	0.0	13	0.0	3.0	0.0	0.0
33	0.0	5.0	0.0	23	0.0	5.0	0.0	0.0
34	0.0	2.9	0.0	13	0.0	2.9	0.0	0.0
35	0.0	2.7	0.0	12	0.0	2.7	0.0	0.0
36	0.0	4.8	0.0	21	0.0	4.8	0.0	0.0
37	0.0	4.7	0.0	21	0.0	4.7	0.0	0.0
38	0.0	3.1	0.0	13	0.0	3.1	0.0	0.0
39	0.0	2.6	0.0	11	0.0	2.6	0.0	0.0
40	0.0	3.6	0.0	16	0.0	3.6	0.0	0.0
41	0.0	4.0	0.0	17	0.0	4.0	0.0	0.0
42	0.0	2.6	0.0	11	0.0	2.6	0.0	0.0
43	0.0	2.0	0.0	8.2	0.0	2.0	0.0	0.0
44	0.0	2.5	0.0	9.4	0.0	2.5	0.0	0.0
45	0.0	2.6	0.0	9.5	0.0	2.6	0.0	0.0
46	0.0	2.4	0.0	8.9	0.0	2.4	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

TABLE 63. - SHORT-TERM CONDITIONS AT WASHINGTON NATIONAL AIRPORT

	1 Hour	6 AM-9 AM	3 Hour	8 Hour	24 Hour		
Day	Friday 1/2/70	Tuesday 1/6/70	Thursday 1/1/70	Thursday 1/1/70	Thursday - Friday 1/2/70 - 1/3/70		
Time	6 PM-7 PM	6 AM-9 AM	5 PM-8 PM	10 AM-6 PM	10 AM-6 PM	6 PM-2 AM	2 AM-10 AM
Wind Speed Class	1	1	1	1	Same as 8 Hour	2	2
Stability Class	5	5	5	3		5	5
Wind Direction, deg	320	200	290	350		325	330
Wind Persistence, deg	20	20	20	100		35	40
Mixing Height, m	980	880	980	1250		545	750
Aircraft Activity	34	42	82	245		132	94
Direction of Movement	N	S	N	N		N	N
Idle Time at Runway, sec	300	60	220	250		80	40
Fractional Activity:							
-Heating Plant	3	3	3	3		3.3	3
-Surroundings	1.3	1.3	1.3	1.3		1.3	1.3

TABLE 64 - SHORT-TERM CONDITIONS AT J. F. KENNEDY INTERNATIONAL AIRPORT

	1 Hour	6 AM- 9 AM	3 Hour	8 Hour	24 Hour		
Day	Friday 11/27/70	Friday 11/16/70	Friday 11/27/70	Friday 11/27/70	Friday - Saturday 11/27/70 - 11/28/70		
Time	6 PM- 7 PM	6 AM- 9 AM	6 PM- 9 PM	2 PM- 10 PM	2 PM- 10 PM	10 PM- 6 AM	6 AM- 2 PM
Wind Speed Class	1	1	1	1	Same as 8 Hour	1	2
Stability Class	5	5	5	4		5	4
Wind Direction, deg	200	235	220	205		240	205
Wind Persistence, deg	10	150	40	110		60	150
Mixing Height, m	960	960	910	1000		810	1100
Aircraft Activity	30	55	85	224		21	158
Direction of Movement	S	0.5S 0.5W	SW	SW		0.5SW 0.5NW	SW
Idle Time at Runway, sec	540	120	480	480		0.0	180
Fractional Activity:							
-Heating Plant	1.1	3.0	1.1	1.1		1.2	1.1
-Surroundings	1.1	1.3	1.1	1.1		1.1	1.1

TABLE 65 - SHORT-TERM CONDITIONS AT LOS ANGELES INTERNATIONAL AIRPORT

	1 Hour	6 AM- 9 AM	3 Hour	8 Hour	24 Hour		
Day	Thursday 1/1/70	Thursday 1/1/70	Thursday 1/1/70	Thursday 1/8/70	Thursday 1/8/70		
Time	9 PM- 10 PM	6 AM- 9 AM	7 PM 10 PM	8 AM- 4 PM	8 AM- 4 PM	4 PM- 12 PM	12 PM- 8 AM
Wind Speed Class	1	2	1	2	Same as 8 Hour	2	2
Stability Class	5	5	5	4		5	5
Wind Direc- tion, deg	90	68.5	135	190		110	95
Wind Persist- ence, deg	40	23	130	180		60	10
Mixing Height, m	535	635	600	860		600	535
Aircraft Activity	54	62	140	366		327	86
Direction of Movement	E	E	0.15W 0.85E	0.5W 0.5E		E	E
Idle Time at Runway, sec	240	60	210	180		120	0.0
Fractional Activity: -Heating Plant -Surroundings	4.4 1.3	6.6 1.3	4.0 1.3	2.2 1.2		3.0 1.3	5.9 1.3

TABLE 66 - SHORT-TERM CONDITIONS AT CHICAGO-O'HARE INTERNATIONAL AIRPORT

	1 Hour	6 AM- 9 AM	3 Hour	8 Hour	24 Hour		
Day	Friday 3/6/70	Tuesday 1/13/70	Tuesday 1/13/70	Tuesday 1/13/70	Monday - Tuesday 1/12/70 - 1/13/70		
Time	7 PM- 8 PM	6 AM- 9 AM	12 AM- 3 PM	9 AM- 5 PM	9 AM- 5 PM	5 PM- 1 AM	1 AM- 9 AM
Wind Speed Class	1	1	1	1	Same as 8 Hour	2	2
Stability Class	6	6	3	3		6	6
Wind Direc- tion, deg	215	220	255	275		255	240
Wind Persist- ence, deg	30	20	10	90		30	60
Mixing Height, m	700	800	1150	1050		500	500
Aircraft Activity	49	126	161	416		237	135
Direction of Movement	SW	SW	W	W		W	SW
Idle Time at Runway, sec	260	180	320	280		120	60
Fractional Activity:							
-Heating Plant	1.3	3.2	2.5	2.6		2.8	3.2
-Surroundings	1.3	1.3	1.3	1.3		1.3	1.3

TABLE 67 - SHORT-TERM CONDITIONS AT TAMiami AIRPORT

	1 Hour	6 AM-9 AM	3 Hour	8 Hour	24 Hour		
Day	Sunday 1/10/71		Sunday 12/13/70	Thursday 1/21/71	Thursday - Friday 1/21/71 - 1/22/71		
Time	9 AM-10 AM		9 AM-12 Noon	9 AM-5 PM	9 AM-5 PM	5 PM-1 AM	1 AM-9 AM
Wind Speed Class	1	No Activity	2	2	Same as 8 Hour	2	2
Stability Class	2		3	4		4	4
Wind Direction, deg	215		250	30		355	330
Wind Persistence, deg	50		60	140		70	40
Mixing Height, m	1300		1350	1350		910	910
Aircraft Activity	50	0.0	150	400	Same as 8 Hour	250	0.0
Direction of Movement	W	0.0	W	E		0.5N 0.5W	N
Idle Time at Runway, sec	0.0	0.0	0.0	0.0		0.0	0.0
Fractional Activity:							
-Heating Plant	0.0	0.0	0.0	0.0		0.0	0.0
-Surroundings	1.0	1.0	1.0	1.0		1.0	1.0

**TABLE 68a - SHORT-TERM MAXIMA CONCENTRATIONS AT
WASHINGTON NATIONAL AIRPORT**

Receptor Points (See Figs 21 and 22)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	31	84	52	330	56	1600
2	14	90	26	500	0.1	1800
3	8.6	110	16	770	0.0	1500
4	52	130	76	380	72	1900
5	0.4	67	0.5	170	0.0	1400
6	140	220	280	480	3.9	380
7	7.7	43	16	130	380	1200
8	31	90	52	440	0.0	870
9	0.5	47	1.2	140	1300	2700
10	94	150	180	460	0.0	370
11*	0.9	47	1.8	140	460	1900
12*	1.0	47	2.3	140	150	1600
13	0.1	53	0.4	140	160	1400
14	1.2	37	2.4	120	340	1400
15	9.8	42	20	120	280	1400
16	15	63	31	170	370	900
17	94	170	180	400	0.8	310
18	37	88	190	250	0.0	220
19	40	85	68	270	0.0	140
20	17	74	29	300	0.0	47
21	11	59	19	230	0.0	620
22	9.0	62	14	220	0.0	2300
23	7.4	72	12	310	0.0	2100
24	4.3	88	8.0	430	0.0	2200
25	5.5	150	9.6	1200	0.0	1900
Allowable:						
Primary		260				160**
Secondary		150				160**

* Invalid receptor locations.

** Non-methane hydrocarbons.

**TABLE 68a - SHORT-TERM MAXIMA CONCENTRATIONS AT
WASHINGTON NATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 21 and 22)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	6.1	98	10	290	0.0	1700
27	8.6	110	14	320	0.0	1600
28	6.1	88	13	300	0.0	1300
29	2.6	81	5.2	220	0.0	570
30	0.0	23	0.0	100	0.0	880
31	0.0	3.7	0.0	17	0.7	710
32	0.0	80	0.0	110	90	6000
33	0.0	110	0.0	150	0.1	28
34	0.0	170	0.1	230	0.0	260
35	0.1	220	0.4	330	0.0	11
36	0.9	60	1.9	130	0.0	3.5
37	4.3	58	7.6	210	0.0	0.0
38	3.9	41	6.4	140	0.0	0.0
39	1.7	50	2.6	200	0.0	0.0
40	1.4	32	3.7	140	0.0	2300
41	0.6	30	1.2	110	0.0	0.0
42	0.3	26	0.5	110	0.0	0.0
43	0.1	47	0.1	220	0.0	14
44	0.0	1.1	0.0	5.0	0.0	900
45	0.0	8.3	0.0	40	0.0	480
46	0.0	63	0.0	470	0.0	1600
48	170	240	310	550	1500	3000
49	150	210	290	620	1700	3000
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

**TABLE 68b - SHORT-TERM MAXIMA CONCENTRATIONS AT
WASHINGTON NATIONAL AIRPORT**

Receptor Points (See Figs 21 and 22)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	1.4	3.4	4.6	28	8.7	74	0.0	190
2	1.0	4.2	0.0	27	4.9	230	13	440
3	0.3	7.4	0.0	15	3.1	570	0.0	350
4	0.6	4.2	2.3	25	9.1	110	0.0	130
5	0.0	4.1	0.0	1.9	0.1	90	0.0	140
6	11	13	110	120	44	130	19	270
7	0.1	2.1	0.7	6.1	4.0	51	52	150
8	1.6	3.5	1.3	5.7	7.1	320	0.0	170
9	0.0	2.7	0.0	3.3	0.2	63	0.0	200
10	9.7	12	0.6	14	28	220	5.6	280
11*	0.0	2.9	0.0	2.5	0.4	63	0.2	160
12*	0.0	2.9	0.0	2.6	0.5	63	3.8	160
13	0.0	2.9	0.0	1.2	0.1	77	0.0	200
14	0.0	2.1	0.0	5.6	0.5	47	280	470
15	0.1	2.0	1.0	5.9	4.6	44	39	150
16	0.2	2.4	0.6	9.2	7.1	68	55	160
17	5.4	7.4	45	59	28	120	31	340
18	1.6	3.2	5.5	18	8.4	74	25	1700
19	0.9	2.4	3.1	15	13	170	12	230
20	0.8	2.5	0.9	8.2	4.6	210	0.0	53
21	0.6	2.1	0.0	1.4	3.1	140	0.0	6.5
22	0.3	2.3	0.0	0.0	2.1	93	0.0	32
23	0.2	3.1	0.0	0.0	1.8	190	0.0	130
24	0.2	2.5	0.0	0.1	1.6	430	0.0	370
25	0.2	3.0	0.0	1.3	1.9	1500	0.0	380
Allowable:								
Primary		10	Secondary		40	365		
		10			40	260	1300	

* Invalid receptor locations.

**TABLE 68b - SHORT-TERM MAXIMA CONCENTRATIONS AT
WASHINGTON NATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 21 and 22)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.2	3.8	0.0	7.8	2.0	110	0.0	400
27	0.2	3.7	0.0	20	2.6	120	0.0	240
28	0.0	4.0	0.0	27	3.4	110	0.0	120
29	0.0	1.9	0.0	0.0	1.2	97	0.0	500
30	0.0	0.7	0.0	0.0	0.0	67	0.0	3700
31	0.0	0.7	0.0	0.0	0.0	4.3	0.0	12
32	0.0	4.0	0.0	0.0	0.0	130	0.0	230
33	0.0	4.4	0.0	0.0	0.0	240	0.0	140
34	0.0	0.7	0.0	0.0	0.0	260	0.0	58
35	0.0	4.3	0.0	6.4	0.1	330	7.8	320
36	0.0	2.7	0.0	4.6	0.4	93	12	290
37	0.1	2.6	1.4	9.7	0.8	110	0.5	38
38	0.1	1.6	0.0	4.8	1.2	73	0.0	170
39	0.1	1.5	0.0	23	0.5	67	0.0	40
40	0.1	2.1	0.0	6.0	0.5	43	0.0	80
41	0.0	2.6	0.0	0.4	0.2	40	0.0	140
42	0.0	1.8	0.0	0.1	0.1	32	0.0	0.0
43	0.0	1.5	0.0	24	0.0	33	0.0	0.0
44	0.0	0.2	0.0	0.0	0.0	1.3	0.0	630
45	0.0	1.6	0.0	0.0	0.0	10	0.0	0.0
46	0.0	1.5	0.0	0.0	0.0	80	0.0	0.0
48	12	14	110	120	50	140	140	330
49	11	13	100	110	46	310	400	670
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

**TABLE 69 a - SHORT-TERM MAXIMA CONCENTRATIONS AT
J. F. KENNEDY INTERNATIONAL AIRPORT**

Receptor Points (See Flgs 23 and 24)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	64	120	60	1600	2900	4500
2	48	82	52	2100	1300	3200
3	37	250	39	4200	2000	4600
4	36	290	37	9600	1100	3500
5	80	260	78	1400	1600	3400
6	52	200	57	400	1500	2800
7	48	150	63	250	1700	2500
8	56	87	77	170	1100	2200
9	57	60	70	77	7300	8400
10	45	53	63	84	150	670
11	42	120	53	1300	510	1000
12	43	65	79	180	870	1800
13	0.1	13	0.2	36	0.1	180
14	8.5	120	17	350	990	1100
15	0.0	120	0.0	340	0.0	310
16	190	470	600	1800	1600	2300
17	110	280	3.0	500	4.5	16
18	250	270	340	470	990	1600
19	89	190	80	1600	3700	6400
20	53	130	79	930	950	1900
21	95	250	140	1300	900	1500
22	120	310	180	1100	830	1500
23	31	82	55	230	740	1000
24	12	160	21	490	440	760
25	18	140	35	400	380	850
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

**TABLE 69a - SHORT-TERM MAXIMA CONCENTRATIONS AT
J. F. KENNEDY INTERNATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 23 and 24)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.7	360	1.5	770	2.2	21
27	0.0	100	0.0	280	0.0	250
28	0.8	300	1.9	840	0.3	3.7
29	120	260	2.8	150	0.1	550
30	0.0	86	0.8	98	0.0	62
31	0.1	3.7	0.3	11	0.0	760
32	0.7	52	1.1	150	0.0	650
33	23	51	36	380	110	980
34	37	100	56	1100	310	1500
35	14	170	21	810	180	900
36	17	180	26	900	150	2800
37	18	200	28	800	170	1800
38	16	130	24	630	190	570
39	6.1	180	11	600	220	610
40	1.9	74	3.2	280	230	570
41	0.0	210	0.0	700	68	260
42	0.0	200	0.0	250	0.0	1500
43	0.0	34	0.0	96	0.0	44
44	0.0	780	0.0	2200	0.0	54
45	0.0	140	0.0	380	0.0	5500
46	0.0	160	0.0	350	0.0	0.0
47	0.0	77	0.0	220	0.0	2.9
48	0.1	2.3	0.2	6.7	0.0	670
49	4.1	89	7.5	310	14	1300
50	12	88	18	260	150	610
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

**TABLE 69b - SHORT-TERM MAXIMA CONCENTRATIONS AT
J. F. KENNEDY INTERNATIONAL AIRPORT**

Receptor Points (See Figs 23 and 24)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	8.6	19	85	100	17	30	53	180
2	3.6	17	3.7	45	14	70	14	350
3	3.1	26	2.5	44	15	520	14	4900
4	3.5	28	4.2	22	15	760	9.0	92
5	11	18	6.5	6.5	21	91	13	120
6	5.3	8.0	10	10	15	69	13	85
7	4.5	7.6	0.5	0.5	17	57	13	28
8	4.0	5.0	0.0	0.5	25	35	5.3	210
9	6.9	7.0	6.0	18	20	20	69	380
10	4.1	4.4	0.0	20	20	23	0.0	120
11	3.5	10	8.0	26	9.5	150	7.9	38
12	1.6	2.4	0.5	0.5	16	25	53	73
13	0.0	0.4	0.0	0.0	0.1	4.7	0.0	0.0
14	0.0	3.6	0.0	0.0	3.9	47	0.2	400
15	0.0	4.0	0.0	0.0	0.0	47	0.0	260
16	19	21	890	890	90	340	1800	2000
17	0.0	2.3	0.0	0.0	0.6	62	0.0	210
18	22	23	980	980	69	79	1300	1300
19	12	20	2.4	24	21	300	79	320
20	3.5	8.8	6.4	16	16	150	23	180
21	6.1	10	5.4	5.4	25	350	40	300
22	8.0	9.7	1.5	1.5	33	230	330	500
23	0.4	2.2	0.0	0.0	9.5	30	63	180
24	0.4	3.5	0.0	0.0	4.2	56	6.9	110
25	0.1	1.8	0.0	0.0	8.4	55	51	220
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

**TABLE 69b - SHORT-TERM MAXIMA CONCENTRATIONS AT
J. F. KENNEDY INTERNATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 23 and 24)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.0	1.6	0.0	0.0	0.3	100	0.0	94
27	0.0	3.3	0.0	0.0	0.0	137	0.0	220
28	0.0	2.7	0.0	0.0	0.4	110	0.0	240
29	0.0	1.7	0.0	0.0	0.6	20	0.0	200
30	0.0	1.1	0.0	30	0.0	13	0.0	30
31	0.0	0.1	0.0	0.0	0.1	1.5	0.0	0.0
32	0.0	1.6	0.0	0.0	0.2	20	0.0	0.0
33	0.9	3.4	0.1	0.2	4.2	14	1.8	1.8
34	2.1	8.6	0.4	17	15	100	4.4	16
35	1.0	3.7	0.7	11	4.1	73	1.6	130
36	1.1	6.7	4.3	10	4.8	73	4.8	610
37	1.0	3.8	4.4	6.8	5.3	88	23	200
38	0.9	6.8	0.0	3.8	4.9	66	34	61
39	0.1	0.4	0.0	0.0	2.3	68	0.5	53
40	0.0	2.4	0.0	0.0	0.5	27	0.0	17
41	0.0	0.3	0.0	0.0	0.0	80	0.0	50
42	0.0	2.3	0.0	0.0	0.0	21	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	13	0.0	0.0
44	0.0	13	0.0	0.0	0.0	290	0.0	0.0
45	0.0	4.2	0.0	0.0	0.0	50	0.0	0.0
46	0.0	5.1	0.0	0.0	0.0	60	0.0	0.0
47	0.0	2.6	0.0	0.0	0.0	29	0.0	0.0
48	0.0	0.1	0.0	0.0	0.1	0.9	0.0	0.0
49	0.0	2.0	0.0	0.6	1.3	36	0.0	0.0
50	0.6	4.7	0.0	0.0	3.2	54	0.0	10
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

TABLE 70a - SHORT-TERM MAXIMA CONCENTRATIONS AT LOS ANGELES INTERNATIONAL AIRPORT

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total
1	12	21	15	160	490	970
2	8.7	15	14	140	2.6	560
3	14	31	22	120	330	1000
4	14	37	20	160	0.0	650
5	16	38	23	150	0.0	1000
6	13	37	22	160	0.0	1100
7	19	33	37	140	1200	1500
8	15	23	27	97	0.0	440
9	37	51	61	170	170	430
10	26	33	41	170	0.0	560
11	66	91	120	250	490	910
12	28	29	42	52	0.0	27
13	51	76	87	200	560	950
14	13	60	21	250	0.0	1.6
15	7.3	14	14	100	0.0	350
16	9.0	20	17	100	0.0	310
17	1.8	67	0.3	320	0.0	510
18	3.0	8.0	6.0	81	0.0	1500
19	4.7	9.3	8.3	40	0.0	300
20	0.7	35	1.5	160	0.0	0.0
21	0.0	19	0.2	98	0.0	0.9
22	0.0	26	0.2	380	82	140
23	0.0	23	0.2	130	89	330
24	0.0	27	0.1	140	86	450
25	0.0	24	0.1	120	130	530
Allowable:						
Primary		260			160*	
Secondary		150			160*	

* Non-methane hydrocarbons.

TABLE 70a - SHORT-TERM MAXIMA CONCENTRATIONS AT LOS ANGELES INTERNATIONAL AIRPORT
(CONTINUED)

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total
26	1.3	19	0.2	89	270	690
27	9.3	14	16	80	96	460
28	14	24	28	110	0.0	260
29	9.3	14	18	76	0.0	310
30	4.3	20	8.7	120	0.0	91
31*	50	55	83	100	0.0	33
32*	57	60	87	110	0.0	37
33	0.6	5.7	1.2	28	0.0	1.8
34	0.7	10	1.4	52	0.0	0.0
35	0.9	48	1.5	230	0.0	0.0
36	0.8	9.0	1.4	47	0.0	1500
37	0.5	4.3	0.7	25	0.0	0.0
38	0.0	35	0.0	170	0.0	0.0
39	0.0	3.3	0.0	17	0.0	70
40	0.0	0.4	0.0	1.9	0.0	350
41	0.0	16	0.0	76	0.0	310
42	0.0	0.0	0.0	0.0	0.0	440
43	0.0	7.0	0.0	26	18	500
44	0.0	23	0.0	110	170	510
45	5.0	13	9.0	73	10	300
46	5.0	70	10	340	0.0	270
47	1.8	46	3.3	240	0.0	140
48	0.9	23	1.6	110	0.0	220
49	280	300	470	610	700	960
50	610	630	1000	1100	380	780
Allowable:						
Primary		260				160**
Secondary		150				160**

* Invalid receptor locations.

** Non-methane hydrocarbons.

**TABLE 70b - SHORT-TERM MAXIMA CONCENTRATIONS AT
LOS ANGELES INTERNATIONAL AIRPORT**

Receptor Points (See Figs 25 and 26)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	2.2	4.0	3.4	23	5.1	15	47	320
2	1.5	2.9	0.1	6.0	5.1	28	20	730
3	1.3	2.5	3.6	13	8.1	29	59	170
4	0.7	2.0	5.2	10	7.2	34	64	110
5	0.9	1.8	5.8	24	10	38	30	69
6	1.1	2.4	1.3	2.4	9.7	38	33	46
7	0.5	1.1	33	42	9.7	31	72	180
8	2.4	3.4	0.0	11	7.6	18	47	140
9	0.3	1.0	32	45	12	49	160	230
10	6.6	8.3	0.0	9.7	12	21	21	130
11	0.8	1.8	57	65	26	58	280	460
12	6.7	6.9	0.0	0.0	11	13	2.1	200
13	0.0	1.0	55	62	17	50	220	430
14	1.3	2.0	0.0	0.0	4.7	65	0.0	140
15	1.2	2.1	0.0	11	4.2	12	47	97
16	1.0	2.3	0.0	18	5.1	18	14	67
17	0.3	1.4	0.0	12	1.0	84	4.2	170
18	0.4	1.9	0.0	0.2	1.8	75	21	82
19	0.8	1.9	0.0	0.0	2.4	8.7	15	90
20	0.0	1.9	0.0	0.0	0.5	43	0.0	430
21	0.0	0.8	0.0	16	0.0	24	0.0	6.6
22	0.0	0.2	0.0	43	0.0	25	0.0	76
23	0.0	1.1	0.0	15	0.0	28	0.2	76
24	0.0	1.3	0.0	11	0.0	34	1.5	98
25	0.0	1.6	1.1	9.7	0.0	30	8.1	270
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

TABLE 70b - SHORT-TERM MAXIMA CONCENTRATIONS AT
LOS ANGELES INTERNATIONAL AIRPORT (CONTINUED)

Receptor Points (See Figs 25 and 26)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.0	0.2	5.8	11	0.6	21	19.	120
27	0.0	0.3	5.4	22	3.3	21	23.	98
28	0.4	1.3	2.9	11	9.3	26	36.	120
29	0.6	1.5	2.0	12	6.4	15	76.	340
30	0.6	1.4	0.0	1.0	2.7	32	35.	170
31*	6.9	7.3	0.0	0.0	18	23	19.	290
32*	10	11	0.0	0.0	20	27	72.	380
33	0.0	0.7	0.0	5.3	0.3	6.5	68.	86
34	0.0	0.8	0.0	4.1	0.4	35	3.8	36
35	0.1	1.1	0.0	2.3	0.4	59	0.6	240
36	0.1	1.8	0.0	0.0	0.4	10	0.0	110
37	0.0	0.9	0.0	0.0	0.2	5.8	0.0	8.5
38	0.0	1.3	0.0	0.0	0.0	45	0.0	69
39	0.0	0.7	0.0	2.3	0.0	4.3	0.0	180
40	0.0	0.0	0.0	4.1	0.0	0.5	0.0	61
41	0.0	0.5	0.0	5.3	0.0	20	0.0	9.4
42	0.0	0.0	0.0	1.9	0.0	0.0	0.0	100
43	0.0	0.0	0.0	4.1	0.0	9.0	0.0	20
44	0.0	0.0	2.2	7.3	0.0	29	10	75
45	0.0	0.1	3.8	16	1.7	19	16	89
46	0.1	0.4	0.5	17	2.7	84	11	66
47	0.0	1.3	0.0	4.7	1.1	61	10	170
48	0.0	0.9	0.0	1.9	0.4	27	8.9	110
49	0.5	1.4	83	95	93	120	380	460
50	1.3	1.8	250	260	210	230	590	790
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

* Invalid receptor locations.

**TABLE 71a - SHORT-TERM MAXIMA CONCENTRATIONS AT
CHICAGO-O'HARE INTERNATIONAL AIRPORT**

Receptor Points (See Figs 27 and 28)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	22	35	23	280	0.0	18
2	31	32	32	33	270	270
3	18	18	30	31	1200	1200
4	7.3	12	14	36	2.4	2.4
5	12	15	22	37	640	640
6	12	13	22	27	620	620
7	91	93	150	160	35000	35000
8	4.3	47	9.0	210	0.0	5200
9	50	82	87	280	89	2800
10	4.3	6.0	7.0	13	0.0	750
11	150	180	240	670	14000	17000
12	0.1	13	0.0	59	0.0	0.0
13	160	170	270	360	4000	4400
14	2.3	13	4.0	54	820	870
15	80	200	120	1400	530	2200
16	0.0	42	0.0	200	0.0	0.0
17	26	27	43	50	0.0	2300
18	6.3	17	10	64	5000	5200
19	33	39	60	83	2900	3400
20	20	40	35	160	3400	6700
21	27	54	42	410	1500	12000
22	26	41	44	260	4800	5800
23	34	67	59	270	5.9	3400
24	7.7	8.7	15	23	0.0	6600
25	2.2	19	4.7	86	0.0	4600
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

**TABLE 71a - SHORT-TERM MAXIMA CONCENTRATIONS AT CHICAGO-O'HARE
INTERNATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 27 and 28)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.5	90	1.0	410	0.0	840
27	0.4	1.2	0.7	4.7	0.0	790
28	0.0	0.7	0.0	3.7	0.0	0.0
29	0.0	22	0.0	110	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	1.0
31	0.0	8.0	0.0	40	0.0	0.0
32	0.0	0.6	0.0	2.9	0.0	32
33	0.6	8.0	1.2	36	550	820
34	0.2	10	0.4	47	310	1600
35	1.3	6.8	2.3	28	1700	1900
36	7.6	16	13	60	1400	3900
37	10	82	17	420	930	3400
38	14	27	24	96	0.0	8100
39	7.0	38	12	170	0.0	0.0
40	2.7	38	4.7	170	0.0	0.0
41	1.2	35	2.4	140	0.0	0.0
42	0.1	4.7	0.2	22	0.0	1.1
43	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.1	0.1
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

**TABLE 71b - SHORT-TERM MAXIMA CONCENTRATIONS AT
CHICAGO-O'HARE INTERNATIONAL AIRPORT**

Receptor Points (See Figs 27 and 28)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	3.3	12	21	41	18	27	31	36
2	3.9	3.9	0.0	23	22	22	37	41
3	2.6	2.6	7.9	10	16	16	12	17
4	1.1	1.2	23	23	5.6	14	2.3	4.3
5	1.3	1.5	0.5	0.5	9.1	13	7.7	8.7
6	1.6	1.8	3.0	3.0	9.1	10	0.2	0.2
7	12	12	250	250	65	68	2000	2000
8	0.3	0.7	0.0	0.2	3.1	56	4.6	59
9	4.2	6.6	0.0	0.2	33	67	77	77
10	1.6	1.9	0.0	4.0	5.4	6.4	0.0	0.0
11	12	18	49	54	100	380	490	530
12	0.0	0.1	0.0	0.0	0.0	13	0.0	17
13	12	14	11	20	100	110	540	540
14	0.0	0.7	3.8	3.8	1.2	13	0.0	0.0
15	14	32	2.9	12	63	91	14	56
16	0.0	1.2	0.0	0.0	0.0	42	0.0	19
17	3.4	3.6	0.0	22	18	19	0.0	0.6
18	0.2	1.6	9.7	9.7	4.9	18	7.7	10
19	3.4	3.7	7.9	18	25	30	15	18
20	0.9	1.4	7.8	25	14	21	28	29
21	2.0	4.5	2.1	25	21	44	29	49
22	1.4	6.5	4.3	8.5	18	30	20	24
23	3.8	6.2	0.0	0.0	24	62	21	21
24	0.7	1.0	0.0	21	5.4	6.4	7.0	26
25	0.1	0.9	0.0	25	1.5	23	0.8	23
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

**TABLE 71b - SHORT-TERM MAXIMA CONCENTRATIONS AT
CHICAGO-O'HARE INTERNATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 27 and 28)	CO (mg/m^3)				SO ₂ ($\mu\text{g}/\text{m}^3$)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.0	1.7	0.0	20	0.2	110	0.0	110
27	0.0	0.2	0.0	31	0.2	1.0	0.0	0.0
28	0.0	0.2	0.0	0.0	0.0	0.7	0.0	0.0
29	0.0	0.5	0.0	0.0	0.0	23	0.0	79
30	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0
31	0.0	0.2	0.0	0.0	0.0	8.0	0.0	0.0
32	0.0	0.1	0.0	0.0	0.0	0.6	0.0	0.0
33	0.0	0.1	2.3	2.5	0.3	7.9	0.0	3.3
34	0.0	1.7	2.3	26	0.1	12	0.0	0.0
35	0.0	0.2	8.5	41	0.9	6.8	0.0	24
36	0.2	1.1	4.2	22	5.4	13	6.1	13
37	0.4	3.6	4.8	5.1	7.7	92	17	130
38	0.5	2.1	0.0	32	9.3	24	18	19
39	0.6	3.3	0.0	0.0	4.6	43	3.5	17
40	0.3	1.3	0.0	0.0	1.8	45	0.9	3.8
41	0.0	1.3	0.0	0.0	0.6	41	0.0	3.0
42	0.0	0.9	0.0	0.0	0.1	6.0	0.0	0.0
43	0.0	0.0	0.0	15	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

**TABLE 72a - SHORT-TERM MAXIMA CONCENTRATIONS AT
TAMiami AIRPORT**

Receptor Points (See Figs 31 and 32)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	0.12	2.2	3.9	12	0.0	0.0
2	0.010	2.1	0.0	8.3	0.0	0.0
3	0.53	2.4	2.1	10	0.0	0.0
4	0.024	1.3	0.0	4.7	0.0	0.0
5	0.62	2.2	2.4	9.9	0.0	0.0
6	0.63	2.1	2.0	8.2	0.0	0.0
7	0.22	2.3	0.9	8.3	0.0	0.0
8	0.070	1.7	0.3	6.9	0.0	0.0
9	0.38	2.1	1.5	7.7	0.0	0.0
10	0.0	2.5	0.1	9.4	0.0	0.0
11	0.71	2.2	2.8	8.2	0.0	0.0
12	0.50	1.6	2.2	6.8	0.0	0.0
13	0.11	1.8	0.2	6.4	0.0	0.0
14	0.98	2.4	2.6	9.0	0.0	0.0
15	0.0	2.3	0.0	8.0	0.0	0.0
16	0.0	2.7	0.0	10	0.0	0.0
17	0.0	2.7	0.0	10	0.0	0.0
18	0.0	2.1	0.0	8.3	0.0	0.0
19	0.0	1.7	0.0	5.7	0.0	0.0
20	0.0	0.7	0.0	5.7	0.0	0.0
21	0.30	1.3	1.1	4.4	0.0	0.0
22	0.37	1.2	1.5	5.3	0.0	0.0
23	0.43	1.8	1.9	11	0.0	0.0
24	0.33	2.0	1.2	7.5	0.0	0.0
25	0.18	1.5	0.5	5.0	0.0	0.0
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

**TABLE 72a - SHORT-TERM MAXIMA CONCENTRATIONS AT
TAMiami AIRPORT (CONTINUED)**

Receptor Points (See Figs 31 and 32)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		Total Hydrocarbons ($\mu\text{g}/\text{m}^3$)	
	24 Hr Period		24 Hr Period		(6 AM-9 AM Period)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.0	1.5	0.2	5.4	0.0	0.0
27	0.0	1.5	0.0	5.7	0.0	0.0
28	0.0	1.1	0.0	29	0.0	0.0
29	0.0	1.2	0.0	5.0	0.0	0.0
30	0.0	1.8	0.0	6.0	0.0	0.0
31	0.0	1.3	0.0	6.0	0.0	0.0
32	0.0	4.7	0.0	3.2	0.0	0.0
33	0.0	2.5	0.0	12	0.0	0.0
34	0.0	5.7	0.0	27.	0.0	0.0
35	0.0	2.7	0.0	13	0.0	0.0
36	0.0	2.3	0.0	10	0.0	0.0
37	0.0	1.4	0.0	2.5	0.0	0.0
38	0.0	2.2	0.0	5.0	0.0	0.0
39	0.0	1.4	0.5	5.0	0.0	0.0
40	0.0	2.3	0.6	7.7	0.0	0.0
41	0.0	1.9	0.0	9.0	0.0	0.0
42	0.0	1.8	0.0	5.0	0.0	0.0
43	0.0	1.0	0.0	2.7	0.0	0.0
44	0.0	0.4	0.0	1.4	0.0	0.0
45	0.0	0.8	0.0	2.5	0.0	0.0
46	0.0	0.5	0.0	1.2	0.0	0.0
47	0.2	2.0	1.0	8.4	0.0	0.0
48	0.6	0.9	1.4	4.2	0.0	0.0
Allowable:						
Primary		260				160*
Secondary		150				160*

* Non-methane hydrocarbons.

TABLE 72b - SHORT-TERM MAXIMA CONCENTRATIONS AT TAMIAMI AIRPORT

Receptor Points (See Figs 31 and 32)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air-craft	Total	Air-craft	Total	Air-craft	Total	Air-craft	Total
1	0.2	0.3	0.1	0.2	0.0	3.1	0.0	0.6
2	0.0	0.2	0.2	0.3	0.0	3.1	0.0	0.4
3	0.4	0.6	0.9	1.0	0.0	1.9	0.0	1.0
4	0.0	0.1	0.8	1.0	0.0	1.3	0.0	1.4
5	0.8	0.8	0.0	0.1	0.0	3.3	0.0	1.0
6	0.4	0.5	0.0	0.1	0.0	1.5	0.0	0.8
7	0.3	0.5	0.2	0.2	0.0	2.0	0.0	0.7
8	0.1	0.3	0.1	0.2	0.0	0.8	0.0	0.6
9	0.6	0.8	0.1	0.2	0.0	1.7	0.0	0.5
10	0.0	0.2	0.7	0.8	0.0	2.5	0.0	0.6
11	0.9	1.0	0.0	0.1	0.0	1.5	0.0	1.2
12	0.5	0.5	0.0	0.1	0.0	1.3	0.0	0.6
13	0.2	0.4	0.1	0.2	0.0	1.7	0.0	0.5
14	0.5	0.5	0.0	0.1	0.0	1.3	0.0	0.9
15	0.0	0.1	0.2	0.2	0.0	2.3	0.0	0.3
16	0.0	0.1	0.5	0.5	0.0	2.7	0.0	0.3
17	0.0	0.2	0.7	0.7	0.0	2.7	0.0	0.4
18	0.0	0.3	0.2	0.2	0.0	2.1	0.0	0.6
19	0.0	0.2	0.1	0.2	0.0	1.7	0.0	0.7
20	0.0	0.2	0.0	0.1	0.0	1.4	0.0	0.5
21	0.3	0.4	0.0	0.1	0.0	1.0	0.0	0.5
22	0.3	0.3	0.0	0.1	0.0	0.8	0.0	0.6
23	0.3	0.3	0.0	0.1	0.0	1.4	0.0	0.7
24	0.3	0.3	0.0	0.1	0.0	2.5	0.0	0.9
25	0.2	0.3	0.0	0.1	0.0	1.3	0.0	1.1
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

**TABLE 72b - SHORT-TERM MAXIMA CONCENTRATIONS AT
TAMIAHI AIRPORT (CONTINUED)**

Receptor Points (See Figs 31 and 32)	CO (mg/m ³)				SO ₂ (μg/m ³)			
	8 Hr Period		1 Hr Period		24 Hr Period		3 Hr Period	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	0.1	0.3	0.0	0.1	0.0	1.5	0.0	1.8
27	0.1	0.3	0.0	0.1	0.0	1.5	0.0	0.8
28	0.0	0.1	0.0	0.1	0.0	1.1	0.0	0.4
29	0.0	0.2	0.2	0.2	0.0	1.2	0.0	0.4
30	0.0	0.2	0.1	0.2	0.0	1.8	0.0	0.4
31	0.0	0.3	0.0	0.1	0.0	1.2	0.0	0.3
32	0.0	0.0	0.0	0.1	0.0	4.7	0.0	0.6
33	0.0	0.3	0.0	0.1	0.0	2.5	0.0	0.5
34	0.0	0.5	0.0	0.1	0.0	5.7	0.0	1.3
35	0.0	0.1	0.0	0.1	0.0	2.7	0.0	1.0
36	0.0	0.3	0.0	0.1	0.0	2.3	0.0	0.8
37	0.0	0.2	0.0	0.1	0.0	1.5	0.0	0.8
38	0.0	0.2	0.0	0.1	0.0	2.2	0.0	0.5
39	0.0	0.1	0.0	0.2	0.0	1.4	0.0	2.5
40	0.0	0.1	0.0	0.5	0.0	2.3	0.0	0.0
41	0.0	0.2	0.0	0.0	0.0	1.9	0.0	0.8
42	0.0	0.1	0.0	0.0	0.0	1.8	0.0	4.4
43	0.0	0.1	0.0	0.3	0.0	1.0	0.0	0.1
44	0.0	0.1	0.0	0.1	0.0	0.4	0.0	0.0
45	0.0	0.1	0.0	0.1	0.0	0.8	0.0	0.2
46	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.2
47	0.1	0.4	1.6	1.7	0.0	1.1	0.0	0.5
48	0.6	0.7	1.3	1.3	0.0	1.2	0.0	0.6
Allowable:								
Primary		10		40		365		
Secondary		10		40		260		1300

**TABLE 73 - CONTROLLED EMISSION INDEXES:
CONTROL METHOD 1 - COMBUSTION CHAMBER REDESIGN (MINOR)**

Air- craft Class	Engine Class	Engine Power Setting	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)			
				CO	NO _x	Total Hydro- carbons	Particu- lates
2	3	Idle	700	50	3	15 (10)	0.1
		Approach	2500	3	10	2 (1)	0.1
		Take-Off	7000	0.5	20(40)	0.1	0.1
		Cruise	6000	1.2	6	0.1	0.3
3 and 4	2	Idle	500	70(45)	1 (2)	15 (10)	0.1(0.2)
		Approach	1750	4 (6)	2 (6)	2 (1)	0.4(0.5)
		Take-Off	4500	1	6(12)	0.5(0.1)	0.6(0.5)
		Cruise	3500	1	1.5	0.1	0.6
5 and 6	1	Idle	300	100 (25)	1(3)	15 (10)	0.2
		Approach	800	5	2(7)	2 (1)	0.4(0.5)
		Take-Off	1300	2	2.5(1)	1 (0.2)	0.4(0.5)
		Cruise	1000	4	2	0.3	0.4

Note: Controlled emission indexes used in this analysis were preliminary estimates of control method effectiveness from the program described in Reference 6. Final estimates of controlled emission indexes as published in Reference 6, where they differ from the preliminary values, are shown in parentheses.

TABLE 74 - CONTROLLED EMISSION INDEXES:
CONTROL METHOD 11 - COMBUSTION CHAMBER REDESIGN (MAJOR), DIVIDED FUEL
SUPPLY SYSTEM, WATER INJECTION

Air- craft Class	Engine Class	Engine Power Setting	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)			
				CO	NO _x	Total Hydro- carbons	Particu- lates
2	3	Idle	700	25 (12)	3	7 (2)	0.1
		Approach	2500	3	10	2	0.1
		Take-Off	7000	0.5	5 (10)	0.1	0.1
		Cruise	6000	1.2	6	0.1	0.3
3 and 4	2	Idle	500	18 (11)	1	4 (2)	0.05 (0.1)
		Approach	1750	4	2	2	0.2 (0.2)
		Take-Off	4500	1	1.5 (3)	0.5	0.3 (0.2)
		Cruise	3500	1	1.5	0.1	0.3
5 and 6	1	Idle	300	25 (6)	1	4 (2)	0.1
		Approach	800	5	2	2	0.2
		Take-Off	1300	2	0.6 (3)	1	0.2
		Cruise	1000	4	2	0.3	0.2

Note: Controlled emission indexes used in this analysis were preliminary estimates of control method effectiveness from the program described in Reference 6. Final estimates of controlled emission indexes as published in Reference 6, where they differ from the preliminary values, are shown in parentheses.

TABLE 75 - CONTROLLED EMISSION INDEXES:
CONTROL METHOD III - VARIABLE-GEOMETRY COMBUSTION CHAMBER OR STAGED
INJECTION COMBUSTION

Air- craft Class	Engine Class	Engine Power Setting	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)			
				CO	NO _x	Total Hydro- carbons	Particu- lates
2	3	Idle	700	12 (5)	3	4 (1.0)	0.1(0.05)
		Approach	2500	3	10	2	0.1(0.05)
		Take-Off	7000	0.5	5 (20)	0.1	0.1(0.05)
		Cruise	6000	1.2	6	0.1	0.3(0.15)
3 and 4	2	Idle	500	7 (4)	1	1.5(1.0)	0.1(0.05)
		Approach	1750	4	2	2	0.4(0.2)
		Take-Off	4500	1	3(6)	0.5	0.3(0.2)
		Cruise	3500	1	1.5	0.1	0.6(0.3)
5 and 6	1	Idle	300	10(2)	1	1.5(1.0)	0.2(0.1)
		Approach	800	5	2	2	0.4(0.2)
		Take-Off	1300	2	1.2(6)	1	0.4(0.2)
		Cruise	1000	4	2	0.3	0.4(0.2)

Note: Controlled emission indexes used in this analysis were preliminary estimates of control method effectiveness from the program described in Reference 6. Final estimates of controlled emission indexes as published in Reference 6, where they differ from the preliminary values, are shown in parentheses.

**TABLE 76 - CONTROLLED EMISSION INDEXES: CONTROL METHOD IV -
CATALYTIC REACTORS FOR PISTON ENGINES**

Engine Power Setting	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)				
		CO		NO _x	Total Hydro- carbons	Lead
Idle	15	90	(225)	7	22	0.2
Approach	6	82	(210)	3	71	0.2
Take-Off	33	85	(210)	6	8	0.2
Cruise	29	86	(215)	4	7	0.2

Note: Controlled emission indexes used in this analysis were preliminary estimates of control method effectiveness from the program described in Reference 6. Final estimates of controlled emission indexes as published in Reference 6, where they differ from the preliminary values, are shown in parentheses.

TABLE 77 - CONTROLLED EMISSION INDEXES:
CONTROL METHOD V - INCREASE IDLE SPEED, DECREASE NUMBER OF ENGINES IN USE

Air- craft Class	Engine Class	Engine Power Setting	Fuel Flow (kgms/hr)	Emission Index (gms per kgm fuel)			
				CO	NO _x	Total Hydro- carbons	Particu- lates
2	3	High Idle*	1400	9	8	6	0.1
		Approach	2500	3	10	2	0.1
		Take-Off	7000	0.5	20	0.1	0.1
		Cruise	6000	1.2	6	0.1	0.3
3 and 4	2	High Idle*	1000	13	1.5	6	0.23
		Approach	1750	4	2	2	0.4
		Take-Off	4500	1	6	0.5	0.6
		Cruise	3500	1	1.5	0.1	0.6
5 and 6	1	High Idle*	600	13	2	5	0.35
		Approach	800	5	2	2	0.4
		Take-Off	1300	2	2.5	1	0.4
		Cruise	1000	4	2	0.3	0.4

* Minimum number of engines used with high idle.

TABLE 78 - CONTROLLED EMISSION INDEXES:
CONTROL METHOD VI - TOW AIRCRAFT TO ELIMINATE AIRCRAFT ENGINE EMISSIONS
DURING TAXI MODE

Fuel Consumption for Tow Tractors
 (0.44 lb per bhp hr) = 0.27 kgms per kw hr

Tractor Power and Fuel Consumption

Aircraft Class	Tractor Operating Power		Fuel Consumption (kgms per hr)
	hp	kw	
2	240	180	49
3 - 6	135	100	27

Emission Indexes for Diesel Engines After 1970

Emission Indexes (gms per kgm)	CO	NO _x	Total Hydrocarbons	Particulates
	32.2	75.6	3.8	1.5

Tow Distance and Time at Airports
Assuming ATow Speed of 12 km per hr

	Distance (km)	Time (min)
Los Angeles International	4	20
Washington National	2	10
J. F. Kennedy International	5	25
O'Hare International	4	20

TABLE 79a - EMISSION FACTORS:
CONTROL METHOD 1 - COMBUSTION CHAMBER REDESIGN (MINOR)

Idle and Shutdown (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	580	35	180	1.2
3	1200	17	250	1.7
4	380	5.4	81	0.54
5	310	3.1	47	0.63
6	88	0.88	13	0.18

Start-Up and Idle (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	2300	140	700	4.7
3	2300	33	500	3.3
4	1500	22	330	2.2
5	1300	13	190	2.5
6	1100	11	160	2.1

Maintenance (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	2900	1100	820	51
3	2800	170	580	58
4	1800	110	380	37
5	1500	46	220	93
6	1300	39	190	7.8

Taxi, Idle at Runway (grams per sec)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	39	2.3	12	0.078
3	39	0.56	8.3	0.056
4	25	0.36	5.4	0.036
5	21	0.21	3.1	0.042
6	18	0.18	2.6	0.035

TABLE 79b - EMISSION FACTORS:
CONTROL METHOD 1 - COMBUSTION CHAMBER REDESIGN (MINOR)

Approach (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1900	6300	1270	63
3	1900	930	930	190
4	1300	640	640	130
5	750	300	300	60
6	220	90	90	18

Climb-Out (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	420	17000	84	84
3	660	4000	330	400
4	370	2200	190	220
5	390	490	200	79
6	46	57	23	9.1

Landing Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.55	0.033	0.16	0.0011
3	0.60	0.0086	0.13	0.00086
4	0.39	0.0056	0.083	0.00056
5	0.36	0.0036	0.054	0.00072
6	0.39	0.0039	0.058	0.00078

Landing Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	13	0.77	3.8	0.026
3	13	0.18	2.8	0.018
4	5.8	0.083	1.3	0.0083
5	14	0.14	2.1	0.028
6	12	0.12	1.7	0.023

Take-Off Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.13	5.0	0.025	0.025
3	0.16	0.95	0.079	0.095
4	0.13	0.77	0.064	0.077
5	0.10	0.12	0.048	0.019
6	0.064	0.080	0.032	0.013

Take-Off Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	-0.41	-16	-0.082	-0.082
3	-0.37	-2.2	-0.18	-0.22
4	-0.47	-2.8	-0.24	-0.28
5	-0.63	-0.79	-0.32	-0.13
6	-0.51	-0.63	-0.25	-0.10

TABLE 80a - EMISSION FACTORS:
CONTROL METHOD 11 - COMBUSTION CHAMBER REDESIGN (MAJOR), DIVIDED
FUEL SUPPLY SYSTEM, WATER INJECTION

Idle and Shutdown (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	290	35	82	1.2
3	300	17	67	0.83
4	98	5.4	22	0.27
5	78	3.1	13	0.31
6	22	0.88	3.5	0.088

Start-Up and Idle (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1200	140	330	4.7
3	600	33	130	1.7
4	390	22	87	1.1
5	310	13	50	1.3
6	260	11	42	1.1

Maintenance (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1500	1080	390	51
3	780	170	160	29
4	510	110	110	19
5	420	46	62	4.6
6	360	39	52	3.9

Taxi, Idle at Runway (grams per sec)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	19	2.3	5.4	0.078
3	10	0.56	2.2	0.028
4	6.5	0.36	1.4	0.018
5	5.2	0.21	0.83	0.021
6	4.4	0.18	0.70	0.018

TABLE 80b - EMISSION FACTORS:
CONTROL METHOD 11 - COMBUSTION CHAMBER REDESIGN (MAJOR), DIVIDED
FUEL SUPPLY SYSTEM, WATER INJECTION

Approach (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1900	6300	1300	63
3	1900	930	930	93
4	1300	640	640	64
5	750	300	300	30
6	220	90	90	9

Climb-Out (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	420	4200	84	84
3	660	990	330	200
4	370	560	190	110
5	390	120	200	39
6	46	14	23	4.6

Landing Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.27	0.033	0.077	0.0011
3	0.15	0.0086	0.034	0.00043
4	0.10	0.0056	0.022	0.00028
5	0.09	0.0036	0.014	0.00036
6	0.097	0.0039	0.016	0.00039

Landing Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	6.4	0.77	1.8	0.026
3	3.3	0.18	0.74	0.0092
4	1.5	0.083	0.33	0.0042
5	3.5	0.14	0.56	0.014
6	2.9	0.12	0.47	0.012

Take-Off Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.13	1.3	0.025	0.025
3	0.16	0.24	0.079	0.047
4	0.13	0.19	0.064	0.039
5	0.097	0.029	0.048	0.0097
6	0.064	0.019	0.032	0.0064

Take-Off Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	-0.41	-4.1	-0.082	-0.082
3	-0.37	-0.55	-0.18	-0.11
4	-0.47	-0.71	-0.24	-0.14
5	-0.63	-0.19	-0.32	-0.063
6	-0.51	-0.15	-0.25	-0.051

TABLE 81 a - EMISSION FACTORS:
CONTROL METHOD III - VARIABLE-GEOMETRY COMBUSTION CHAMBER
OR STAGED INJECTION COMBUSTION

Idle and Shutdown (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	140	35	47	1.2
3	120	17	25	1.7
4	38	5.4	8.1	0.54
5	31	3.1	4.7	0.63
6	8.8	0.88	1.3	0.18

Start-Up and Idle (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	560	140	190	4.7
3	230	33	50	3.3
4	150	22	33	2.2
5	130	13	19	2.5
6	110	11	16	2.1

Maintenance (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	830	1100	230	51
3	360	170	66	58
4	230	110	43	37
5	210	46	26	9.3
6	170	39	22	7.8

Taxi, Idle at Runway (grams per sec)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	9.3	2.3	3.1	0.078
3	3.9	0.56	0.83	0.056
4	2.5	0.36	0.54	0.036
5	2.1	0.21	0.31	0.042
6	1.8	0.18	0.26	0.035

TABLE 81b - EMISSION FACTORS:
CONTROL METHOD 111 - VARIABLE-GEOMETRY COMBUSTION CHAMBER
OR STAGED INJECTION COMBUSTION

Approach (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1900	6300	1300	63
3	1900	930	930	190
4	1300	640	640	130
5	800	300	300	60
6	220	90	90	18

Climb-Out (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	420	4200	84	84
3	660	2000	330	200
4	370	1100	190	110
5	390	230	200	78
6	46	27	23	9.1

Landing Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.13	0.033	0.044	0.0011
3	0.060	0.0086	0.013	0.00086
4	0.039	0.0056	0.0083	0.00056
5	0.036	0.0036	0.0054	0.00072
6	0.039	0.0039	0.0058	0.00078

Landing Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	3.1	0.77	1.0	0.026
3	1.3	0.18	0.28	0.018
4	0.58	0.083	0.13	0.0083
5	1.4	0.14	0.21	0.028
6	1.2	0.12	0.17	0.023

Take-Off Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.13	1.3	0.025	0.025
3	0.16	0.47	0.079	0.047
4	0.13	0.39	0.064	0.038
5	0.097	0.058	0.048	0.019
6	0.064	0.039	0.032	0.013

Take-Off Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	-0.41	-4.1	-0.082	-0.082
3	-0.037	-1.1	-0.18	-0.11
4	-0.47	-1.4	-0.24	-0.14
5	-0.63	-0.38	-0.32	-0.13
6	-0.51	-0.30	-0.25	-0.10

TABLE 81b - EMISSION FACTORS:
CONTROL METHOD III - VARIABLE-GEOMETRY COMBUSTION CHAMBER
OR STAGED INJECTION COMBUSTION

Approach (grams)

Climb-Out (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates	Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1900	6300	1300	63	2	420	4200	84	84
3	1900	930	930	190	3	660	2000	330	200
4	1300	640	640	130	4	370	1100	190	110
5	800	300	300	60	5	390	230	200	78
6	220	90	90	18	6	46	27	23	9.1

Landing Run - Constant Coefficient
(grams per meter)

Landing Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates	Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	0.13	0.033	0.044	0.0011	2	3.1	0.77	1.0	0.026
3	0.060	0.0086	0.013	0.00086	3	1.3	0.18	0.28	0.018
4	0.039	0.0056	0.0083	0.00056	4	0.58	0.083	0.13	0.0083
5	0.036	0.0036	0.0054	0.00072	5	1.4	0.14	0.21	0.028
6	0.039	0.0039	0.0058	0.00078	6	1.2	0.12	0.17	0.023

Take-Off Run - Constant Coefficient
(grams per meter)

Take-Off Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates	Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particu-lates $\times 10^4$
2	0.13	1.3	0.025	0.025	2	-0.41	-4.1	-0.082	-0.082
3	0.16	0.47	0.079	0.047	3	-0.037	-1.1	-0.18	-0.11
4	0.13	0.39	0.064	0.038	4	-0.47	-1.4	-0.24	-0.14
5	0.097	0.058	0.048	0.019	5	-0.63	-0.39	-0.32	-0.13
6	0.064	0.039	0.032	0.013	6	-0.51	-0.30	-0.25	-0.10

TABLE 82 - EMISSION FACTORS:
CONTROL METHOD IV - CATALYTIC REACTORS FOR PISTON ENGINES

Aircraft Operating Mode	Units	Pollutants			
		CO	NO _x	Total Hydrocarbons	Lead
Idle and Shutdown	grams	1.9	0.15	0.46	0.042
Start-Up and Idle	grams	23	1.8	5.5	0.05
Maintenance	grams	42	2.8	7.6	0.095
Taxi, Idle at Runway	grams per sec	0.38	0.029	0.092	0.00083
Approach	grams	31	1.1	27	0.076
Climb-Out	grams	120	8.3	11	0.28
Landing Run Constant Coefficient	grams per meter	0.013	0.0097	0.0031	0.000028
Landing Run First Degree Coefficient	grams per meter ²	0.63×10^{-4}	0.049×10^{-4}	0.15×10^{-4}	0.0014×10^{-4}
Take-Off Run Constant Coefficient	grams per meter	0.058	0.0041	0.0055	0.00014
Take-Off Run First Degree Coefficient	grams per meter ²	-0.79×10^{-4}	-0.056×10^{-4}	-0.075×10^{-4}	-0.0019×10^{-4}

TABLE 83a - EMISSION FACTORS:
CONTROL METHOD V - INCREASE IDLE SPEED, DECREASE NUMBER OF ENGINES IN USE

Idle and Shutdown (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	110	93	70	1.2
3	220	25	100	3.8
4	76	8.8	35	1.3
5	65	10	25	1.8
6	21	3.3	8.1	0.57

Start-Up and Idle (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	420	370	280	4.7
3	430	50	200	7.7
4	300	35	140	5.4
5	260	40	100	7.0
6	250	39	98	6.8

Maintenance (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	2900	1100	820	51
3	2800	170	580	58
4	1800	110	380	37
5	1500	46	220	9.3
6	1300	39	190	7.8

Taxi, Idle at Runway (grams per sec)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	7.0	6.2	4.7	0.078
3	7.2	0.83	3.3	0.13
4	5.1	0.58	2.3	0.090
5	4.3	0.67	1.7	0.12
6	4.2	0.65	1.6	0.11

TABLE 83b - EMISSION FACTORS:
CONTROL METHOD V - INCREASE IDLE SPEED, DECREASE NUMBER OF ENGINES IN USE

Approach (grams)

Air craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	1900	6300	1300	63
3	1900	930	930	190
4	1300	640	640	130
5	800	300	300	50
6	220	90	90	18

Climb-Out (grams)

Air craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	420	17000	84	84
3	660	4000	330	400
4	370	2200	180	220
5	390	490	200	78
6	46	57	23	9.1

Landing Run - Constant Coefficient
(grams per meter)

Air craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.55	0.0033	0.160	0.0011
3	0.60	0.0086	0.130	0.00086
4	0.39	0.0056	0.083	0.00056
5	0.36	0.0036	0.054	0.00072
6	0.39	0.0039	0.058	0.00078

Landing Run - First Degree Coefficient
(grams per meter²)

Air craft Class	CO x 10 ⁴	NO _x x 10 ⁴	Total Hydro-carbons x 10 ⁴	Particu-lates x 10 ⁴
2	13	0.77	3.83	0.026
3	13	0.18	2.8	0.018
4	5.8	0.083	1.3	0.0083
5	14	0.14	2.1	0.028
6	12	0.12	1.7	0.023

Take-Off Run - Constant Coefficient
(grams per meter)

Air craft Class	CO	NO _x	Total Hydro-carbons	Particu-lates
2	0.13	5.0	0.025	0.025
3	0.16	0.95	0.079	0.095
4	0.13	0.77	0.064	0.077
5	0.097	0.12	0.048	0.019
6	0.064	0.080	0.032	0.013

Take-Off Run - First Degree Coefficient
(grams per meter²)

Air craft Class	CO x 10 ⁴	NO _x x 10 ⁴	Total Hydro-carbons x 10 ⁴	Particu-lates x 10 ⁴
2	-0.41	-16	-0.082	-0.082
3	-0.37	-2.2	-0.18	-0.22
4	-0.47	-2.8	-0.24	-0.28
5	-0.63	-0.79	-0.32	-0.13
6	-0.51	-0.63	-0.25	-0.10

TABLE 84a - EMISSION FACTORS:
CONTROL METHOD VI - TOW AIRCRAFT TO ELIMINATE AIRCRAFT ENGINE EMISSIONS
DURING TAXI MODE

All Emission Factors for Idle
and Shutdown are Zero

All Emission Factors for Start-up
and Idle are Zero

Maintenance (grams)

Air- craft class	CO	NO _x	Total Hydro- carbons	Particu- lates
2	2900	1100	820	51
3	2800	170	580	58
4	1800	110	380	37
5	1500	46	220	9.3
6	1300	39	190	7.8

Taxi, Idle at Runway (grams per sec)

Air- craft class	CO	NO _x	Total Hydro- carbons	Particu- lates
2	0.44	1.0	0.051	0.020
3	0.24	0.57	0.028	0.011
4	0.24	0.57	0.028	0.011
5	0.24	0.57	0.028	0.011
6	0.24	0.57	0.028	0.011

TABLE 84b - EMISSION FACTORS:
CONTROL METHOD VI - TOW AIRCRAFT TO ELIMINATE AIRCRAFT ENGINE EMISSIONS
DURING TAXI MODE

Approach (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	1900	6300	1300	63
3	1900	930	930	190
4	1300	640	640	130
5	750	300	300	60
6	220	90	90	18

Climb-Out (grams)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	420	17000	84	84
3	660	4000	330	400
4	370	2200	190	220
5	390	490	200	78
6	46	57	23	9.1

Landing Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	0.55	0.033	0.16	0.0011
3	0.6	0.0086	0.13	0.00086
4	0.39	0.0056	0.083	0.00056
5	0.36	0.0036	0.054	0.00072
6	0.39	0.0039	0.054	0.00078

Landing Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particulates $\times 10^4$
2	13	0.77	3.8	0.026
3	13	0.18	2.8	0.018
4	5.8	0.083	1.3	0.0083
5	14	0.14	2.1	0.028
6	12	0.12	1.7	0.023

Take-Off Run - Constant Coefficient
(grams per meter)

Air-craft Class	CO	NO _x	Total Hydro-carbons	Particulates
2	0.13	5.0	0.025	0.026
3	0.16	0.95	0.079	0.095
4	0.13	0.77	0.064	0.077
5	0.097	0.12	0.048	0.019
6	0.064	0.080	0.032	0.013

Take-Off Run - First Degree Coefficient
(grams per meter²)

Air-craft Class	CO $\times 10^4$	NO _x $\times 10^4$	Total Hydro-carbons $\times 10^4$	Particulates $\times 10^4$
2	-0.41	-17	-0.082	-0.082
3	-0.37	-2.2	-0.18	-0.22
4	-0.47	-2.8	-0.24	-0.28
5	-0.63	-0.79	-0.32	-0.13
6	-0.51	-0.63	-0.25	-0.10

TABLE 85 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR POINT 3, LOS ANGELES INTERNATIONAL AIRPORT (1 HOUR AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	3600	110	1300	66
I	2800 (100)*	220 (100)	580 (100)	17 (100)
II	860 (31)	89 (40)	180 (31)	9.4 (55)
III	420 (15)	120 (55)	76 (13)	12 (71)
V	640 (23)	260 (120)	250 (43)	24 (140)
VI	180 (6)	220 (100)	15 (3)	15 (88)
Concentrations with Control I as Percentage of Total Concentrations	23	20	27	18

* Numbers in parentheses refer to per cent of the datum value.

TABLE 86 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR
POINT II, LOS ANGELES INTERNATIONAL AIRPORT (1 HOUR AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	57000	2500	22000	1400
I	45000 (100)*	3300 (100)	9800 (100)	270 (100)
II	15000 (33)	2200 (67)	3500 (36)	170 (63)
III	7900 (18)	2400 (73)	1900 (19)	270 (100)
V	12000 (27)	3900 (120)	4700 (48)	410 (150)
VI	4200 (9)	3400 (100)	1000 (10)	280 (100)
Concentrations with Control I as Percentage of Total Concentrations	84	82	86	72

* Numbers in parentheses refer to per cent of the datum value.

**TABLE 87 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR
POINT 26, LOS ANGELES INTERNATIONAL AIRPORT (1 HOUR AVERAGE)**

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	5800	200	2100	110
I	4600 (100)*	320 (100)	960 (100)	20 (100)
II	1500 (33)	170 (53)	320 (33)	14 (70)
III	710 (15)	200 (62)	150 (16)	21 (100)
V	1100 (24)	380 (120)	440 (46)	37 (180)
VI	410 (9)	350 (110)	66 (7)	24 (120)
Concentrations with Control I as Percentage of Total Concentrations	49	44	53	25

* Numbers in parentheses refer to per cent of the datum value.

**TABLE 88 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR
POINT 27, LOS ANGELES INTERNATIONAL AIRPORT (1 HOUR AVERAGE)**

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	5400	330	2100	170
I	4300 (100)*	410 (100)	880 (100)	45 (100)
II	1400 (33)	240 (59)	280 (32)	28 (62)
III	710 (17)	280 (68)	110 (11)	45 (100)
V	2400 (56)	450 (110)	590 (67)	59 (130)
VI	2100 (49)	450 (110)	390 (44)	52 (120)
Concentrations with Control I as Percentage of Total Concentrations	21	21	22	22

* Numbers in parentheses refer to per cent of the datum value.

TABLE 89 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR POINT 45, LOS ANGELES INTERNATIONAL AIRPORT (1 HOUR AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	3800	170	1400	89
I	3000 (100)*	260 (100)	620 (100)	19 (100)
II	960 (32)	130 (50)	210 (34)	13 (68)
III	470 (16)	160 (62)	91 (15)	20 (110)
V	1000 (33)	290 (110)	320 (52)	31 (160)
VI	610 (20)	280 (110)	110 (18)	23 (120)
Concentrations with Control I as Percentage of Total Concentrations	19	19	21	12

* Numbers in parentheses refer to per cent of the datum value.

TABLE 90 - THE EFFECT OF CONTROL METHODS ON TOTAL AIRCRAFT EMISSIONS (1 HOUR PERIOD), LOS ANGELES INTERNATIONAL AIRPORT

Control Method	Pollutants (kgms)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	2000	170	770	97
I	1500 (100)*	260 (100)	340 (100)	22 (100)
II	540 (36)	120 (46)	130 (38)	12 (55)
III	310 (21)	150 (58)	76 (22)	17 (77)
V	510 (34)	280 (110)	180 (53)	27 (120)
VI Includes Tractor Emissions	310 (21)	270 (100)	69 (20)	23 (100)

* Numbers in parentheses refer to per cent of the datum value.

TABLE 91 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR POINT 5, LOS ANGELES INTERNATIONAL AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	1300	19	540	17
I	810	42	170	3.9
II	230	22	51	2.1
III	100	28	21	3.1
V	190	52	76	5.8
VI	53	43	8.8	3.3
Concentrations with Control I as Percentage of Total Concentrations	36	24	42	28

TABLE 92 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR POINT 9, LOS ANGELES INTERNATIONAL AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	210	60	91	25
I	150 (100) *	150 (100)	36 (100)	13 (100)
II	65 (43)	41 (27)	19 (53)	6.8 (52)
III	45 (30)	72 (48)	14 (39)	7.3 (56)
V	74 (49)	150 (100)	24 (67)	14 (110)
VI	58 (39)	150 (100)	16 (44)	13 (100)
Concentrations with Control I as Percentage of Total Concentrations	21	77	27	63

* Numbers in parentheses refer to per cent of the datum value.

**TABLE 93 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR
POINT 12, LOS ANGELES INTERNATIONAL AIRPORT (ANNUAL AVERAGE)**

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	5800	210	2600	120
I	3700 (100)*	280 (100)	810 (100)	29 (100)
II	1200 (32)	180 (64)	290 (36)	16 (55)
III	580 (16)	210 (75)	160 (20)	26 (90)
V	920 (25)	330 (120)	390 (48)	39 (130)
VI	310 (8)	310 (110)	95 (12)	28 (97)
Concentrations with Control : as Percentage of Total Concentrations	82	81	85	75

* Numbers in parentheses refer to per cent of the datum value.

TABLE 94 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR POINT 24, LOS ANGELES INTERNATIONAL AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	210	9.5	88	5.2
I	130 (100)*	22 (100)	28 (100)	2.0 (100)
II	41 (32)	8.0 (36)	9.8 (35)	1.1 (55)
III	20 (15)	12 (55)	4.5 (16)	1.3 (65)
V	37 (28)	23 (100)	14 (50)	2.3 (120)
VI	16 (12)	23 (100)	3.4 (12)	2.0 (100)
Concentrations with Control I as Percentage of Total Concentrations	19	33	22	21

* Numbers in parentheses refer to per cent of the datum value.

**TABLE 95 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR
POINT 27, LOS ANGELES INTERNATIONAL AIRPORT (ANNUAL AVERAGE)**

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	160	7.9	70	4.5
I	100 (100)*	13 (100)	21 (100)	1.6 (100)
II	31 (31)	6.4 (49)	7.2 (34)	0.82 (51)
III	16 (16)	8.4 (65)	3.6 (17)	1.2 (75)
V	46 (46)	14 (110)	13 (62)	1.7 (110)
VI	35 (35)	14 (110)	7.3 (35)	1.5 (94)
Concentrations with Control I as Percentage of Total Concentrations	16	24	19	17

* Numbers in parentheses refer to per cent of the datum value.

TABLE 96 - THE EFFECT OF CONTROL METHODS ON CONCENTRATION AT RECEPTOR POINT 37, LOS ANGELES INTERNATIONAL AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	130	6.0	58	3.4
I	83 (100)*	11 (100)	18 (100)	1.0 (100)
II	26 (31)	5.0 (45)	6.6 (37)	0.56 (56)
III	13 (16)	6.6 (60)	3.4 (19)	0.78 (78)
V	24 (29)	12 (110)	9.2 (51)	1.3 (130)
VI	11 (13)	12 (110)	2.8 (16)	1.0 (100)
Concentrations with Control I as Percentage of Total Concentrations	13	21	16	12

* Numbers in parentheses refer to per cent of the datum value.

**TABLE 97 - THE EFFECT OF CONTROL METHODS ON TOTAL AIRCRAFT EMISSIONS
(ANNUAL), LOS ANGELES INTERNATIONAL AIRPORT**

Control Method	Pollutants (Mgms)			
	CO	NO _x	Total Hydrocarbons	Particulates
Uncontrolled	13000	810	6000	520
I	8300 (100)*	1500 (100)	1800 (100)	140 (100)
II	2700 (33)	640 (43)	710 (39)	76 (54)
III	1500 (18)	870 (58)	410 (23)	100 (71)
V	2700 (33)	1600 (110)	990 (55)	160 (110)
VI Includes Tractor Emissions	1500 (18)	1500 (100)	390 (22)	140 (100)

* Numbers in parentheses refer to per cent of the datum value.

TABLE 98 - THE EFFECT OF CONTROL METHOD IV ON CONCENTRATIONS AT RECEPTOR POINT 10, TAMiami AIRPORT (1 HOUR AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Lead
Uncontrolled	530	3.7	28	0.95
IV	55	4.0	11	0.11
Concentrations with Control as Percentage of Total Concentrations	40	37	45	51

TABLE 99 - THE EFFECT OF CONTROL METHOD IV ON CONCENTRATIONS AT RECEPTOR POINT 17, TAMiami AIRPORT (1 HOUR AVERAGE)

Control Method	Pollutants (ugms per cu m)			
	CO	NO _x	Total Hydrocarbons	Lead
Uncontrolled	510	3.5	28	0.93
IV	51	3.5	11	0.11
Concentrations with Control as Percentage of Total Concentrations	43	41	49	67

TABLE 100 - THE EFFECT OF CONTROL METHOD IV ON CONCENTRATIONS
AT RECEPTOR POINT 32, TAMiami AIRPORT (1 HOUR AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Lead
Uncontrolled	31	0.21	1.2	0.053
IV	3.1	0.21	0.47	0.0064
Concentrations with Control as Percentage of Total Concentrations	2	2	2	72

TABLE 101 - THE EFFECT OF CONTROL METHOD IV ON TOTAL AIRCRAFT EMISSIONS
(1 HOUR PERIOD), TAMIAHI AIRPORT

Control Method	Pollutants (kgms)			
	CO	NO _x	Total Hydrocarbons	Lead
Uncontrolled	290 (100)*	1.9 (100)	16 (100)	0.49 (100)
IV	26 (9)	1.9 (100)	6.1 (38)	0.059 (12)

* Numbers in parentheses refer to per cent of the datum value.

TABLE 102 - THE EFFECT OF CONTROL METHOD IV ON CONCENTRATIONS AT RECEPTOR
POINT 14, TAMIAH! AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydro- carbons	Lead
Uncontrolled	160	1.2	7.5	0.28
IV	16	1.2	3.0	0.034
Concentrations with Control as Percentage of Total Concentrations	10	12	12	86

TABLE 103 - THE EFFECT OF CONTROL METHOD IV ON CONCENTRATIONS AT RECEPTOR
POINT 21, TAMIAHI AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (ugms per cu m)			
	CO	NO _x	Total Hydrocarbons	Lead
Uncontrolled	61	0.44	3.0	0.11
iv	6.1	0.46	1.2	0.013
Concentrations with Control as Percentage of Total Concentrations	4	4	4	58

TABLE 104 - THE EFFECT OF CONTROL METHOD IV ON CONCENTRATIONS AT RECEPTOR POINT 43, TAMiami AIRPORT (ANNUAL AVERAGE)

Control Method	Pollutants (μ gms per cu m)			
	CO	NO _x	Total Hydrocarbons	Lead
Uncontrolled	5.7	0.040	0.30	0.010
IV	0.57	0.040	0.12	0.0011
Concentrations with Control as Percentage of Total Concentrations	Negligible	Negligible	Negligible	59

TABLE 105 - THE EFFECT OF CONTROL METHOD IV ON TOTAL AIRCRAFT
EMISSIONS (ANNUAL), TAMiami AIRPORT

Control Method	Pollutants (Mgms)			
	CO	NO _x	Total Hydro- carbons	Lead
Uncontrolled	1100 (100)*	7.5 (100)	63 (100)	2.0 (100)
IV	110 (10)	7.5 (100)	24 (38)	0.24 (12)

* Numbers in parentheses refer to per cent of the datum value.

TABLE 106 - PROJECTED AIRCRAFT ACTIVITY LEVELS

Airport/ Year	Total Operational Cycles of Aircraft Classes							
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 12
LAX/								
1975	2,200	69,000	69,000	73,000	8,900	2,500	78,000	2,500
1980	7,900	140,000	0	110,000	5,300	3,800	90,000	1,900
DCA/								
1975	0	0	0	93,000	23,000	1,700	51,000	1,700
1980	0	0	0	110,000	12,000	2,200	51,000	1,100
JFK/								
1975	1,800	43,000	43,000	87,000	5,400	880	27,000	880
1980	5,500	71,000	0	100,000	3,650	2,300	56,000	1,200
ORD/								
1975	3,300	38,000	38,000	230,000	23,000	750	24,000	750
1980	11,000	61,000	0	240,000	15,000	1,300	30,000	650
Van Nuys/								
1975	0	0	0	40	40	0	470,000	0
1980	0	0	0	60	60	0	670,000	0

TABLE 107 - FUTURE PROJECTIONS OF TOTAL EMISSIONS

Airport/ Year	Particulates (kg x 10 ⁻⁵)		NO _x -5 (kg x 10 ⁻⁵)		SO ₂ -5 (kg x 10 ⁻⁵)		Lead ⁻² (kg x 10 ⁻²)	
	Aircraft	Total Airport	Aircraft	Total Airport	Aircraft	Total Airport	Aircraft	Total Airport
LAX/ 1970	5.2	5.6	8.1	20	3.9	4.4	6.6	320
1975	5.5	5.7	19	31	4.5	5.1	8.1	200
1980	6.2	6.3	34	43	5.7	6.6	9.3	71
DCA/ 1970	2.1	2.3	3.3	5.6	0.95	2.9	4.8	44
1975	2.2	2.3	3.8	5.9	1.1	3.0	4.6	19
1980	2.6	2.7	4.2	5.9	1.3	3.2	4.6	7.9
JFK/ 1970	5.2	6.0	7.4	28	3.8	8.2	4.1	490
1975	5.0	5.5	14	32	3.8	8.3	3.9	250
1980	5.0	5.3	21	32	4.0	8.7	8.0	71
ORD/ 1970	8.2	9.1	12	35	5.1	5.5	3.0	580
1975	8.8	9.3	20	36	5.5	6.0	3.3	260
1980	10	10	30	40	6.5	7.3	4.1	70
Van Nuys/ 1970	0.029	0.034	0.11	0.25	0.0	0.003	29	33
1975	0.049	0.052	0.18	0.31	0.001	0.005	48	50
1980	0.070	0.071	0.26	0.33	0.001	0.008	69	69

TABLE 107 - FUTURE PROJECTIONS OF TOTAL EMISSIONS (CONTINUED)

Airport Year	CO (kg x 10 ⁻⁶)		Total Hydrocarbons (kg x 10 ⁻⁵)	
	Aircraft	Total Airport	Aircraft	Total Airport
LAX/ 1970	13	25	63	82
1975	12	23	42	59
1980	12	20	26	35
DCA/ 1970	1.7	2.9	3.6	5.9
1975	1.9	2.8	3.9	5.2
1980	2.2	2.6	4.2	4.7
JFK/ 1970	16	34	70	99
1975	13	27	41	62
1980	12	19	21	31
ORD/ 1970	18	36	68	100
1975	16	32	42	65
1980	18	26	28	39
Van Nuys/ 1970	1.5	1.7	0.91	1.2
1975	2.5	2.6	1.5	1.8
1980	3.6	3.7	2.2	2.4

**TABLE 108 - 1975 ANNUAL AVERAGE CONCENTRATIONS AT
LOS ANGELES INTERNATIONAL AIRPORT**

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total	Air-craft	Total
1	17	25	43	150	13	26	0.1	0.1
2	18	27	41	170	13	30	0.1	0.1
3	17	24	46	140	33	130	0.1	0.1
4	17	25	40	160	12	29	0.0	0.0
5	20	29	45	190	15	29	0.1	0.1
6	17	25	43	160	14	130	0.0	0.0
7	11	18	62	110	15	25	0.0	0.0
8	43	51	12	82	32	42	0.1	0.1
9	25	33	180	230	40	50	0.0	0.0
10	93	100	260	340	68	73	0.2	0.2
11	7.2	16	28	82	6.8	18	0.0	0.0
12	140	150	390	450	100	110	0.3	0.3
13	6.0	15	22	76	5.6	17	0.0	0.0
14	100	110	310	1100	78	88	0.2	0.2
15	9.9	17	370	910	9.2	19	0.0	0.0
16	9.6	11	33	110	8.5	20	0.0	0.0
17	4.3	16	16	84	3.9	18	0.0	0.0
18	6.7	16	23	110	5.9	19	0.0	0.0
19	8.6	18	31	140	7.8	21	0.0	0.0
20	6.9	20	26	97	6.5	22	0.0	0.0
21	4.5	19	20	98	4.8	19	0.0	0.0
22	4.6	14	19	140	5.1	20	0.0	0.0
23	5.0	13	20	76	5.6	17	0.0	0.0
24	5.7	13	25	71	6.5	15	0.0	0.0
25	4.2	15	16	74	3.9	17	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

**TABLE 108 - 1975 ANNUAL AVERAGE CONCENTRATIONS AT
LOS ANGELES INTERNATIONAL AIRPORT (CONTINUED)**

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
26	3.5	11	14	55	3.3	13	0.0	0.0
27	5.0	12	19	63	4.3	13	0.0	0.0
28	5.6	14	24	68	6.3	17	0.0	0.0
29	7.3	14	29	75	7.1	17	0.0	0.0
30	3.6	13	14	140	3.3	15	0.0	0.0
31 *	300	300	800	870	210	230	0.6	0.6
32 *	510	520	1400	1400	360	370	1.0	1.0
33	1.3	10	4.6	41	1.1	12	0.0	0.0
34	1.3	10	5.1	42	1.2	12	0.0	0.0
35	1.6	15	6.4	67	1.6	17	0.0	0.0
36	2.7	15	9.8	24	2.4	18	0.0	0.0
37	3.7	11	14	56	3.4	13	0.0	0.0
38	1.7	10	7.4	49	1.8	12	0.0	0.0
39	1.3	13	4.9	12	1.1	16	0.0	0.0
40	1.1	7.4	4.1	35	1.0	8.8	0.0	0.0
41	1.2	6.8	43	72	1.1	8.1	0.0	0.0
42	1.2	7.4	5.2	34	1.2	8.8	0.0	0.0
43	1.4	7.9	6.1	36	1.4	9.4	0.0	0.0
44	1.6	8.1	6.8	37	1.6	9.3	0.0	0.0
45	2.7	9.0	11	43	2.6	10	0.0	0.0
46	1.8	14	7.2	59	1.7	17	0.0	0.0
47	1.4	31	5.5	100	1.4	36	0.0	0.0
48	1.2	13	4.8	49	1.1	16	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

* Invalid receptor locations.

**TABLE 109 - 1980 ANNUAL AVERAGE CONCENTRATIONS AT
LOS ANGELES INTERNATIONAL AIRPORT**

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air- craft	Total	Air- craft	Total	Air- craft	Total	Air- craft	Total
1	23	30	80	160	21	37	0.1	0.1
2	25	33	77	180	23	42	0.1	0.1
3	23	24	85	160	21	35	0.1	0.1
4	21	28	74	170	20	39	0.1	0.1
5	25	32	84	190	23	39	0.1	0.1
6	21	28	79	170	20	34	0.1	0.1
7	12	19	120	160	14	24	0.0	0.0
8	52	59	200	260	51	62	0.1	0.1
9	28	35	370	410	36	46	0.0	0.0
10	110	120	410	480	110	120	0.2	0.2
11	9.0	9.1	52	100	9.0	20	0.0	0.0
12	160	170	630	690	170	180	0.4	0.4
13	7.6	17	41	90	7.5	20	0.0	0.0
14	120	130	500	550	120	130	0.2	0.2
15	12	19	67	110	13	23	0.0	0.0
16	12	20	60	120	12	24	0.0	0.0
17	5.3	16	29	92	5.3	20	0.0	0.0
18	8.6	18	42	110	8.4	22	0.0	0.0
19	11	20	56	140	11	26	0.0	0.0
20	8.5	21	46	110	8.6	25	0.0	0.0
21	5.4	16	37	99	5.7	20	0.0	0.0
22	5.5	15	36	140	5.7	22	0.0	0.0
23	5.9	14	37	87	6.0	17	0.0	0.0
24	6.9	14	47	89	7.1	16	0.0	0.0
25	5.1	16	29	84	5.1	19	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

TABLE 109 - 1980 ANNUAL AVERAGE CONCENTRATIONS AT
LOS ANGELES INTERNATIONAL AIRPORT (CONTINUED)

Receptor Points (See Figs 25 and 26)	Particulates ($\mu\text{g}/\text{m}^3$)		NO ₂ ($\mu\text{g}/\text{m}^3$)		SO ₂ ($\mu\text{g}/\text{m}^3$)		Lead ($\mu\text{g}/\text{m}^3$)	
	Air-craft	Total	Air-craft	Total	Air-craft	Total	Air-craft	Total
26	4.1	12	26	64	4.1	13	0.0	0.0
27	6.0	13	36	75	6.0	15	0.0	0.0
28	6.5	14	44	84	6.8	17	0.0	0.0
29	9.0	16	54	95	9.3	19	0.0	0.0
30	4.4	13	25	70	4.4	17	0.0	0.0
31*	340	350	130	190	330	340	0.7	0.7
32*	580	590	210	270	570	580	1.1	1.1
33	1.4	10	8.4	44	1.4	13	0.0	0.0
34	1.4	10	9.2	46	1.4	12	0.0	0.0
35	1.8	15	12	71	1.8	18	0.0	0.0
36	3.0	15	18	78	3.0	19	0.0	0.0
37	4.4	11	25	64	4.5	14	0.0	0.0
38	1.9	11	14	55	2.0	13	0.0	0.0
39	1.4	13	8.7	63	1.4	16	0.0	0.0
40	1.2	7.5	7.2	37	1.2	9.1	0.0	0.0
41	1.3	6.9	7.8	35	1.4	8.5	0.0	0.0
42	1.4	7.5	9.6	38	1.5	9.1	0.0	0.0
43	1.6	8.1	11	40	1.7	9.8	0.0	0.0
44	1.9	8.3	12	41	2.0	10	0.0	0.0
45	3.2	9.4	20	50	3.2	11	0.0	0.0
46	2.1	15	13	64	2.1	18	0.0	0.0
47	1.5	31	10	110	1.5	36	0.0	0.0
48	1.3	13	8.8	24	1.4	19	0.0	0.0
Allowable:								
Primary		75		100		80		
Secondary		60		100		60		

* Invalid receptor locations.

FIGURES

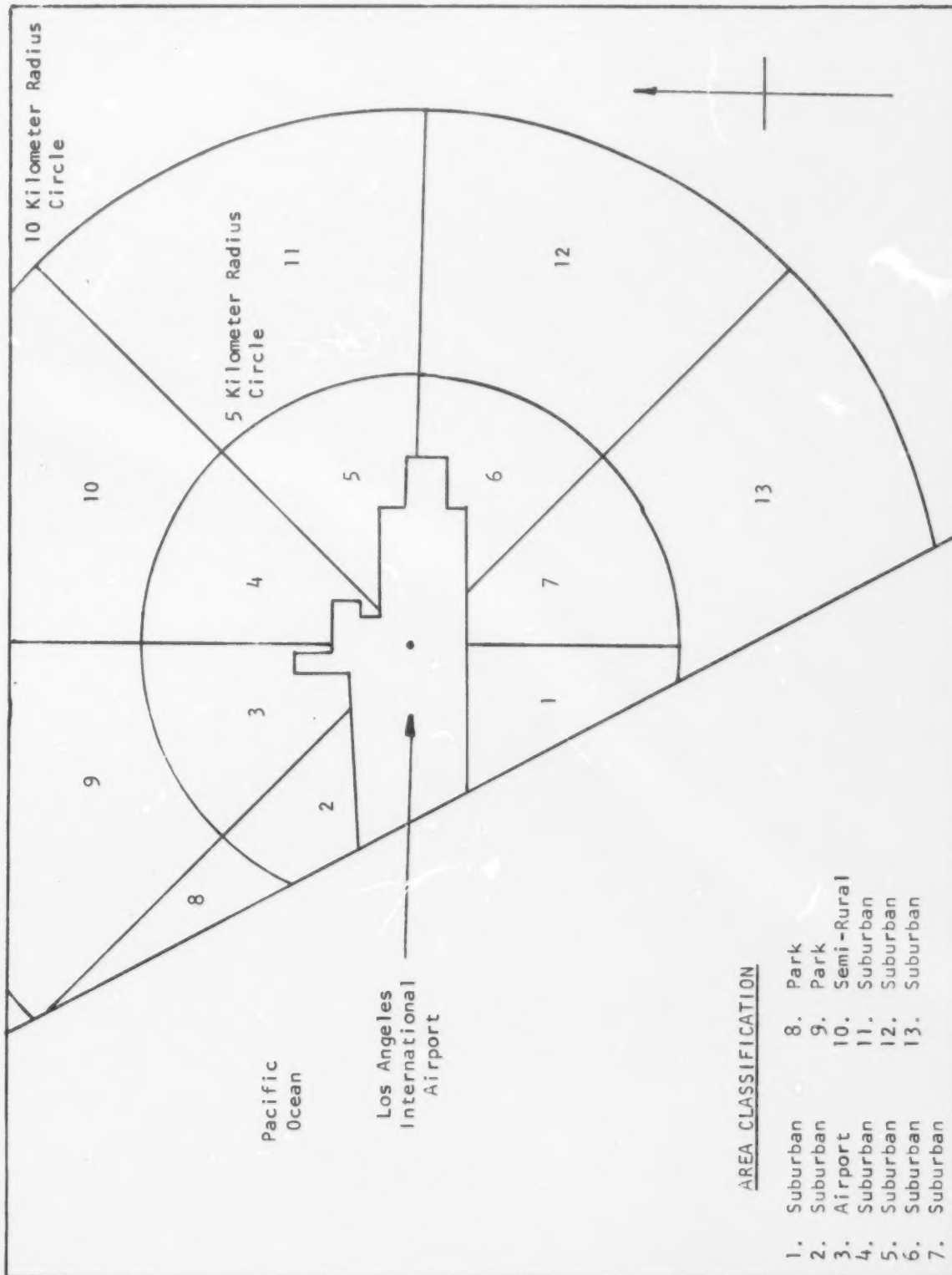


FIGURE 1 - CLASSIFICATION OF SURROUNDINGS OF LOS ANGELES INTERNATIONAL AIRPORT

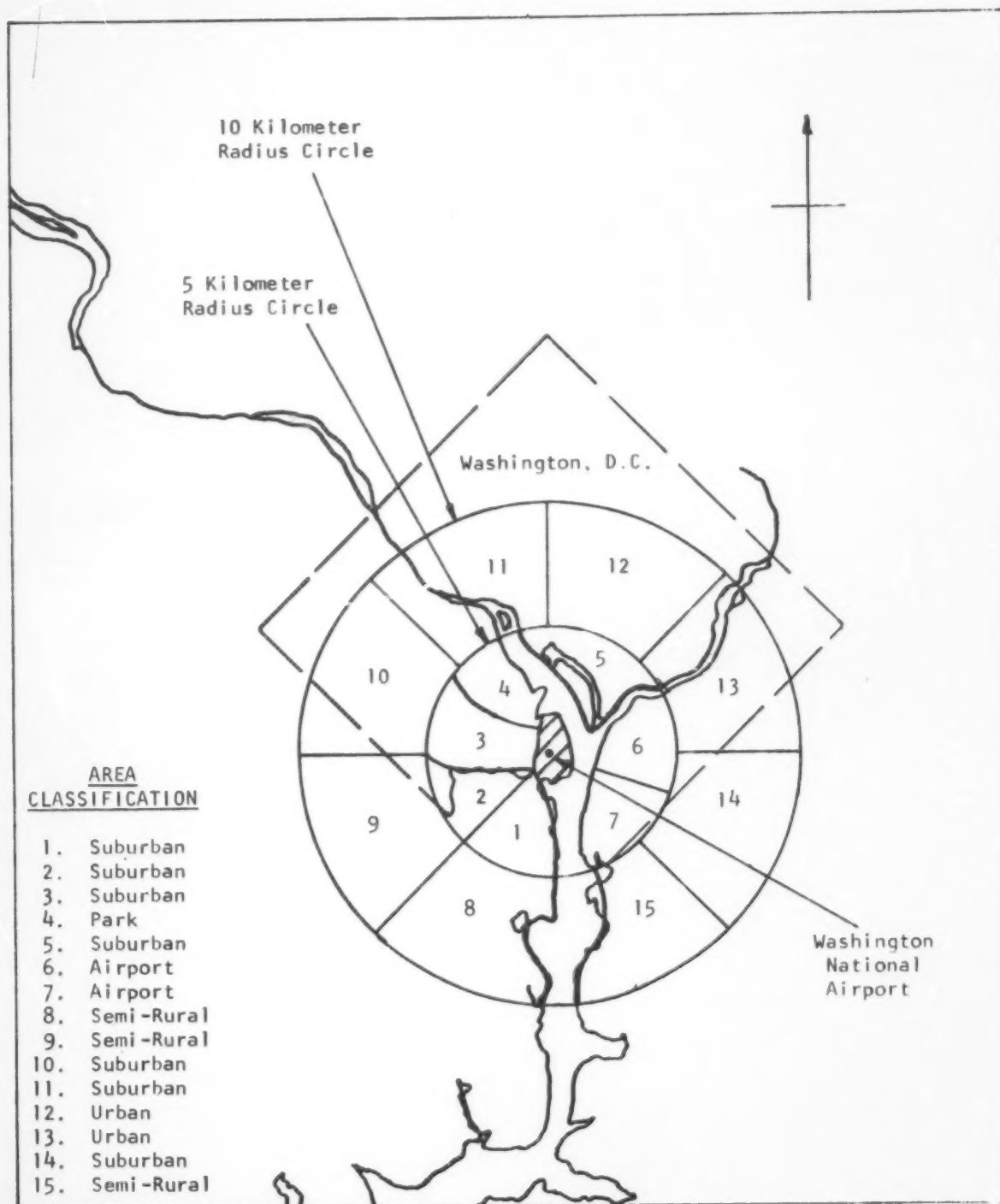


FIGURE 2 - CLASSIFICATION OF SURROUNDINGS OF WASHINGTON NATIONAL AIRPORT

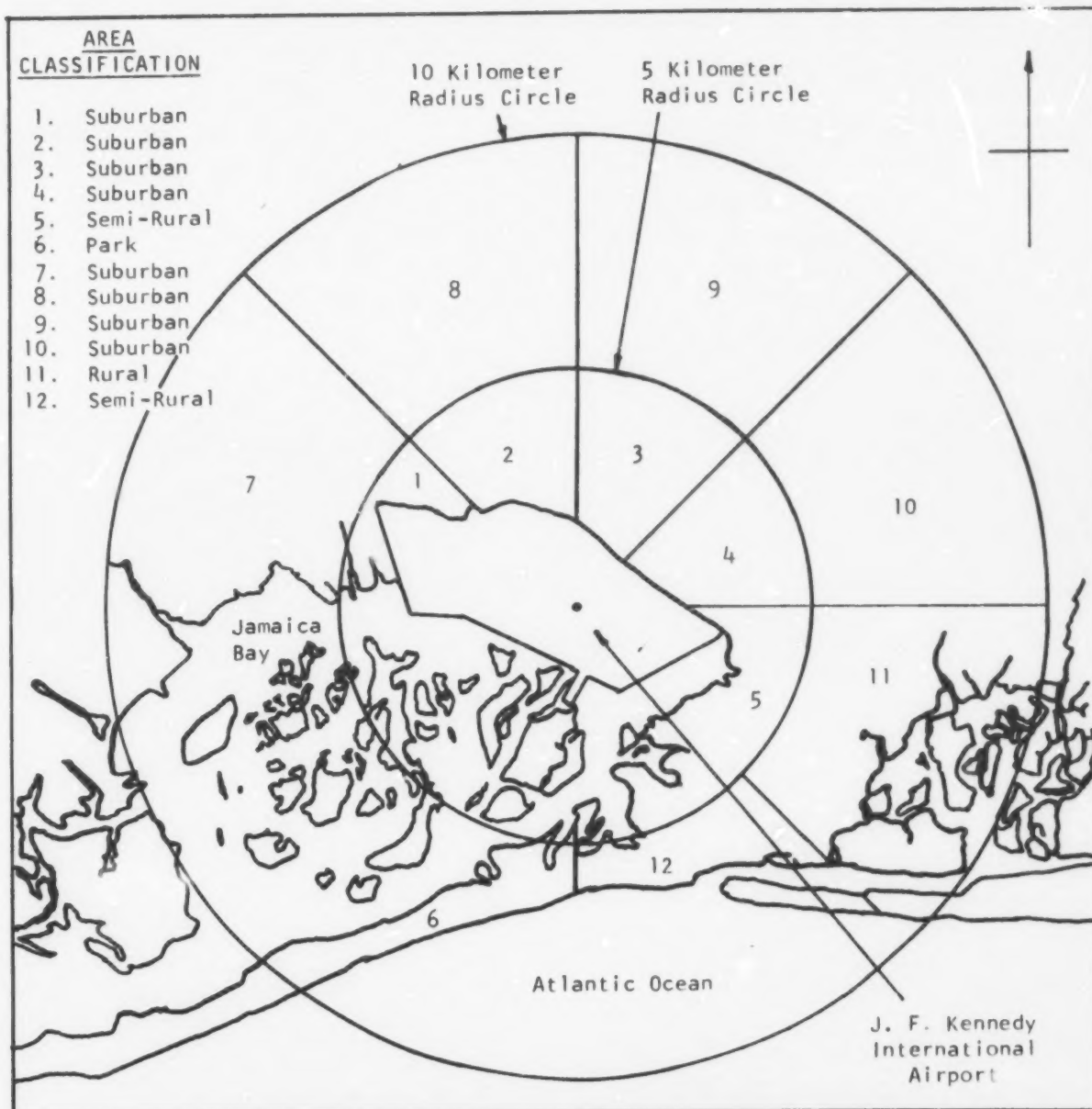


**FIGURE 3 - CLASSIFICATION OF SURROUNDINGS OF
J. F. KENNEDY INTERNATIONAL AIRPORT**

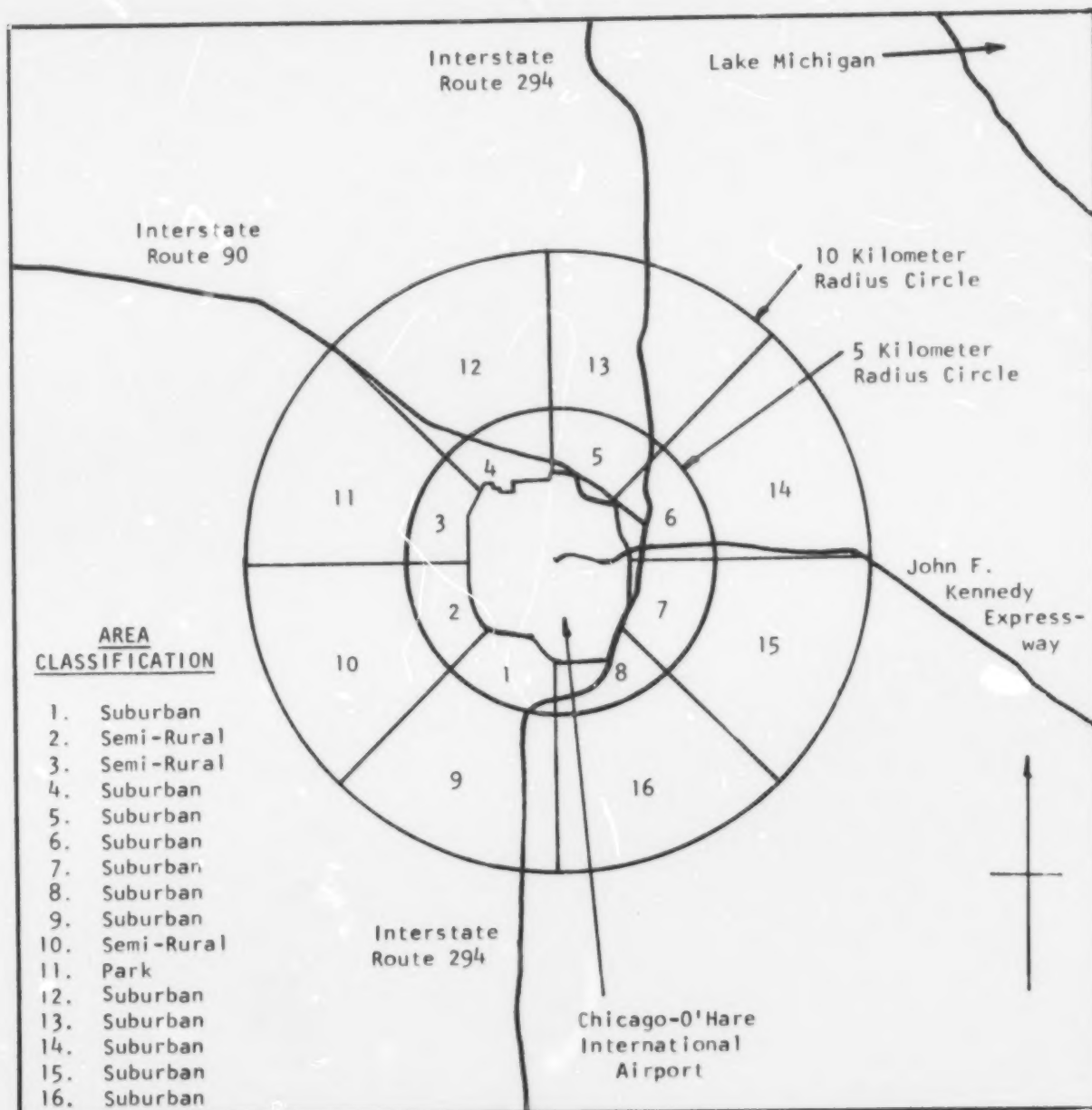


FIGURE 4 - CLASSIFICATION OF SURROUNDINGS OF CHICAGO-O'HARE INTERNATIONAL AIRPORT

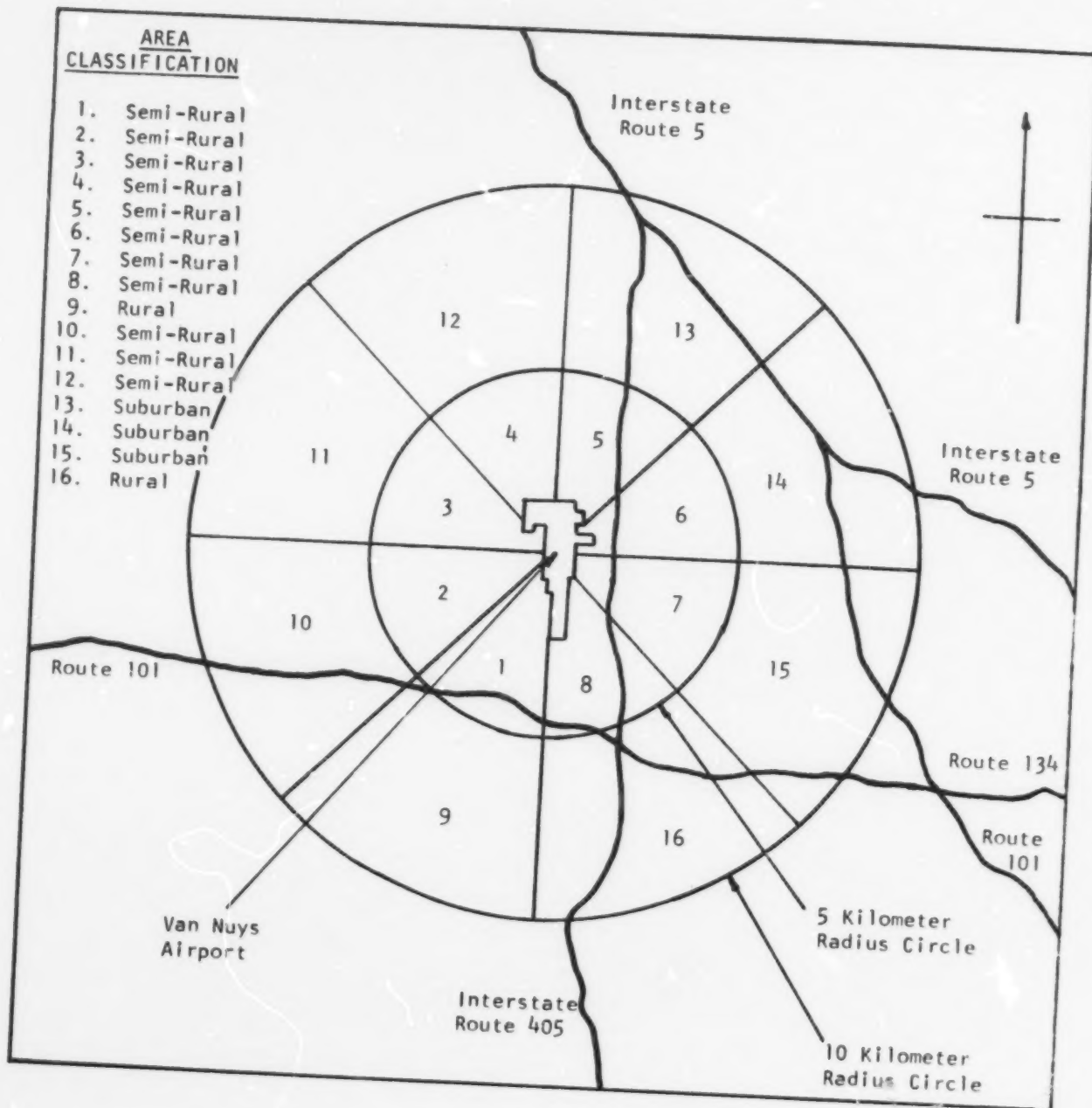


FIGURE 5 - CLASSIFICATION OF SURROUNDINGS OF VAN NUYS AIRPORT

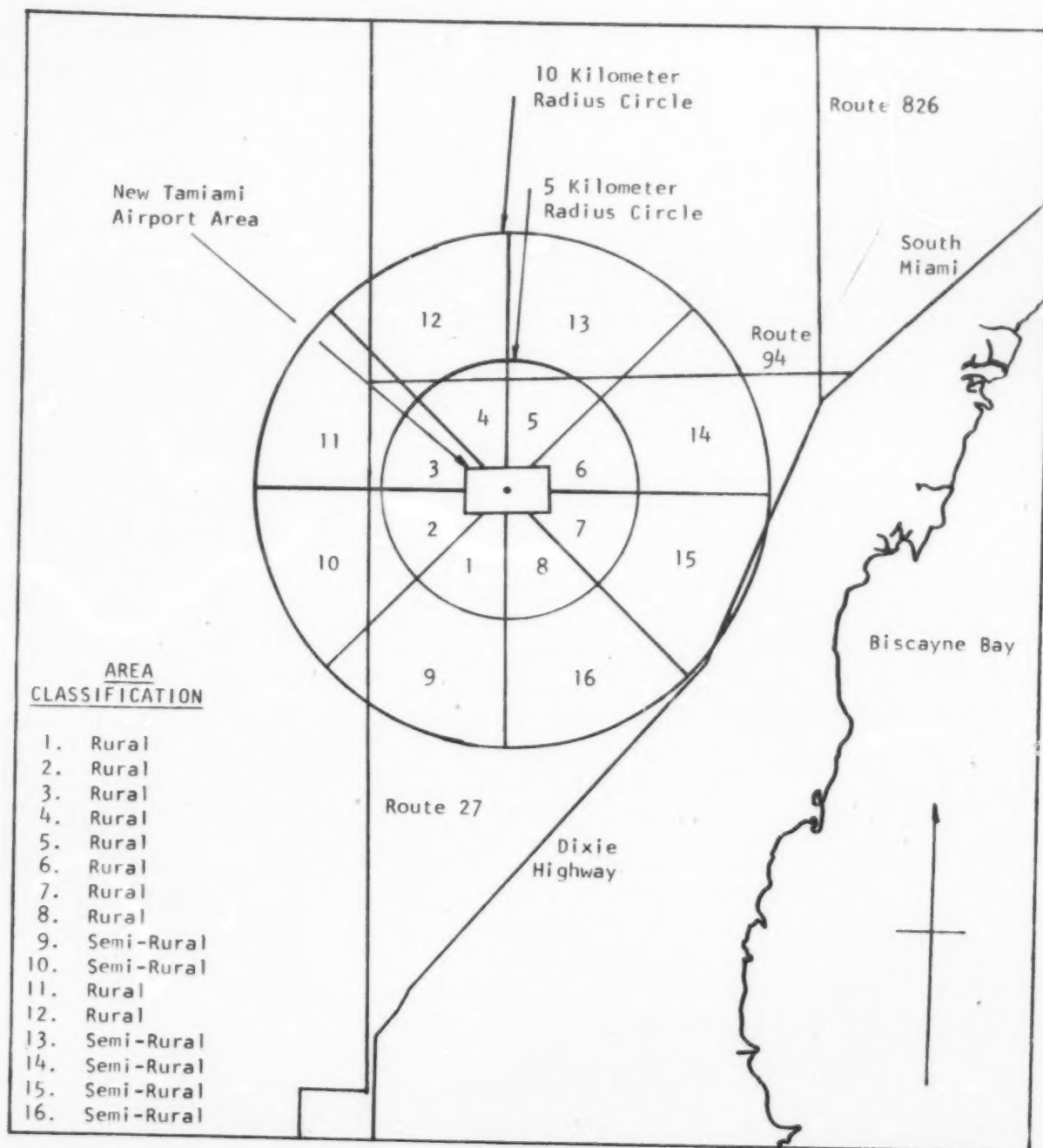


FIGURE 6 - CLASSIFICATION OF SURROUNDINGS OF NEW TAMIAMI AIRPORT

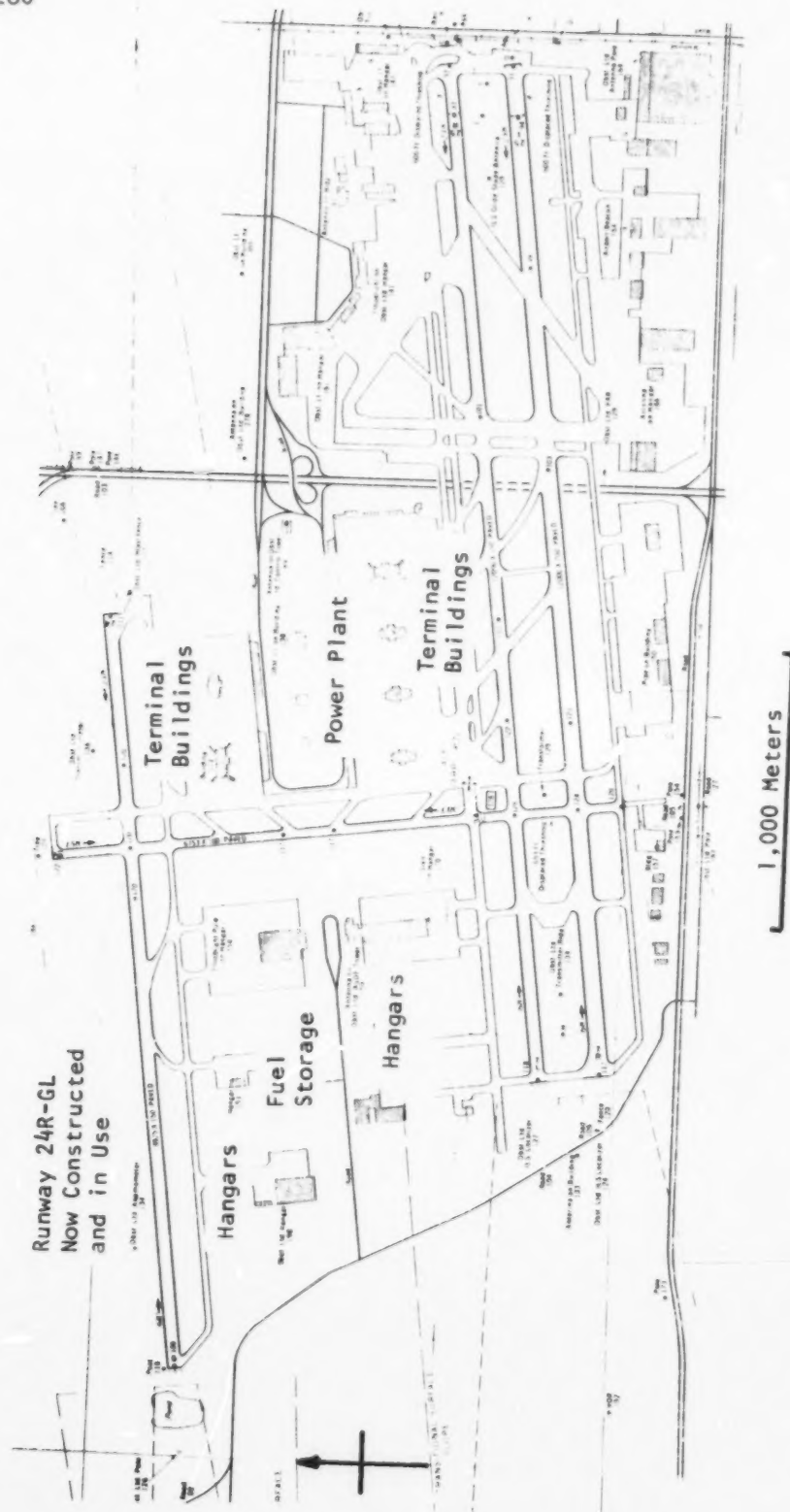


FIGURE 7 - PLAN OF LOS ANGELES INTERNATIONAL AIRPORT



FIGURE 9 - PLAN OF J. F. KENNEDY INTERNATIONAL AIRPORT

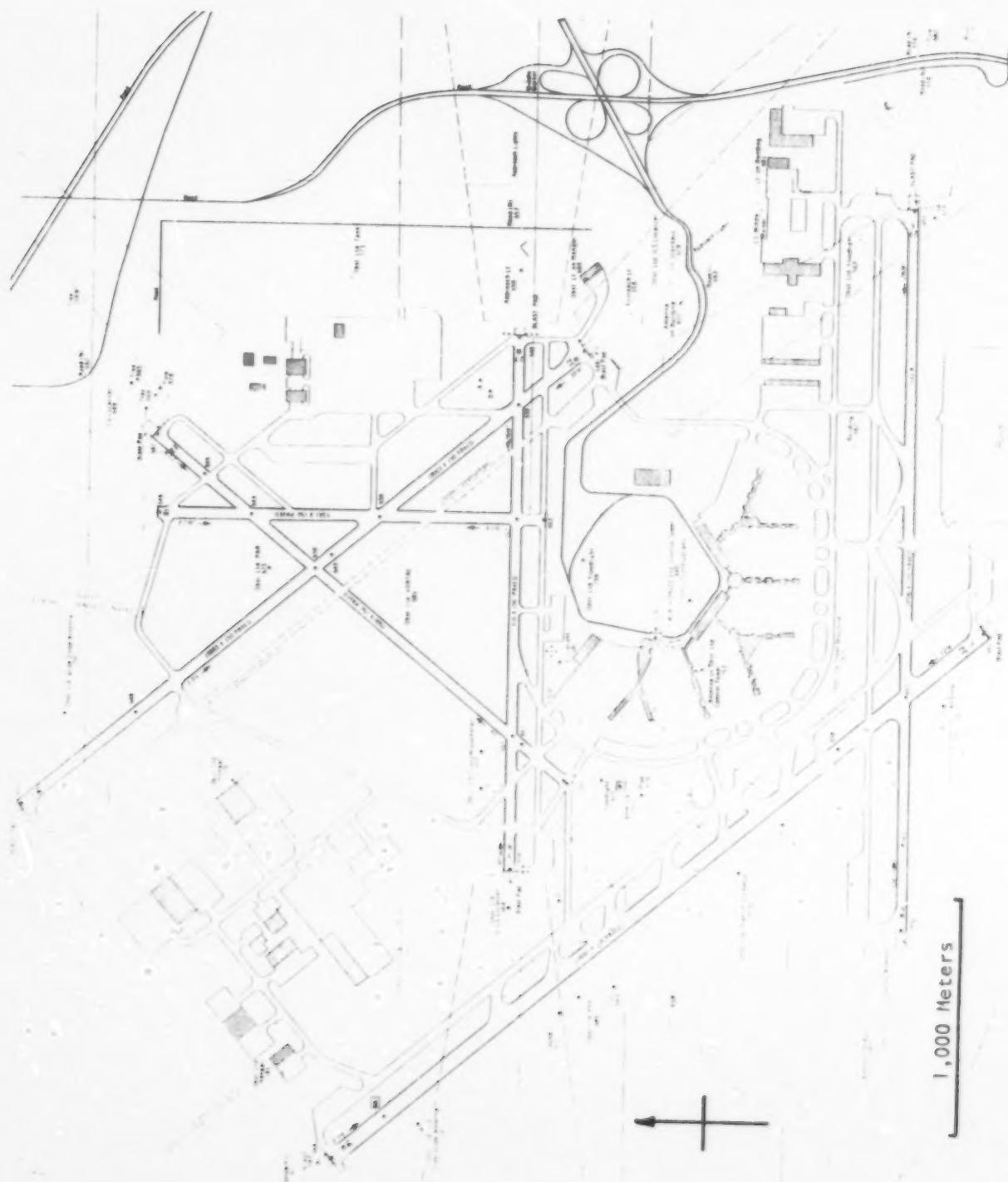


FIGURE 10 - PLAN OF CHICAGO-O'HARE INTERNATIONAL AIRPORT



FIGURE 11 - PLAN OF VAN NUYS AIRPORT

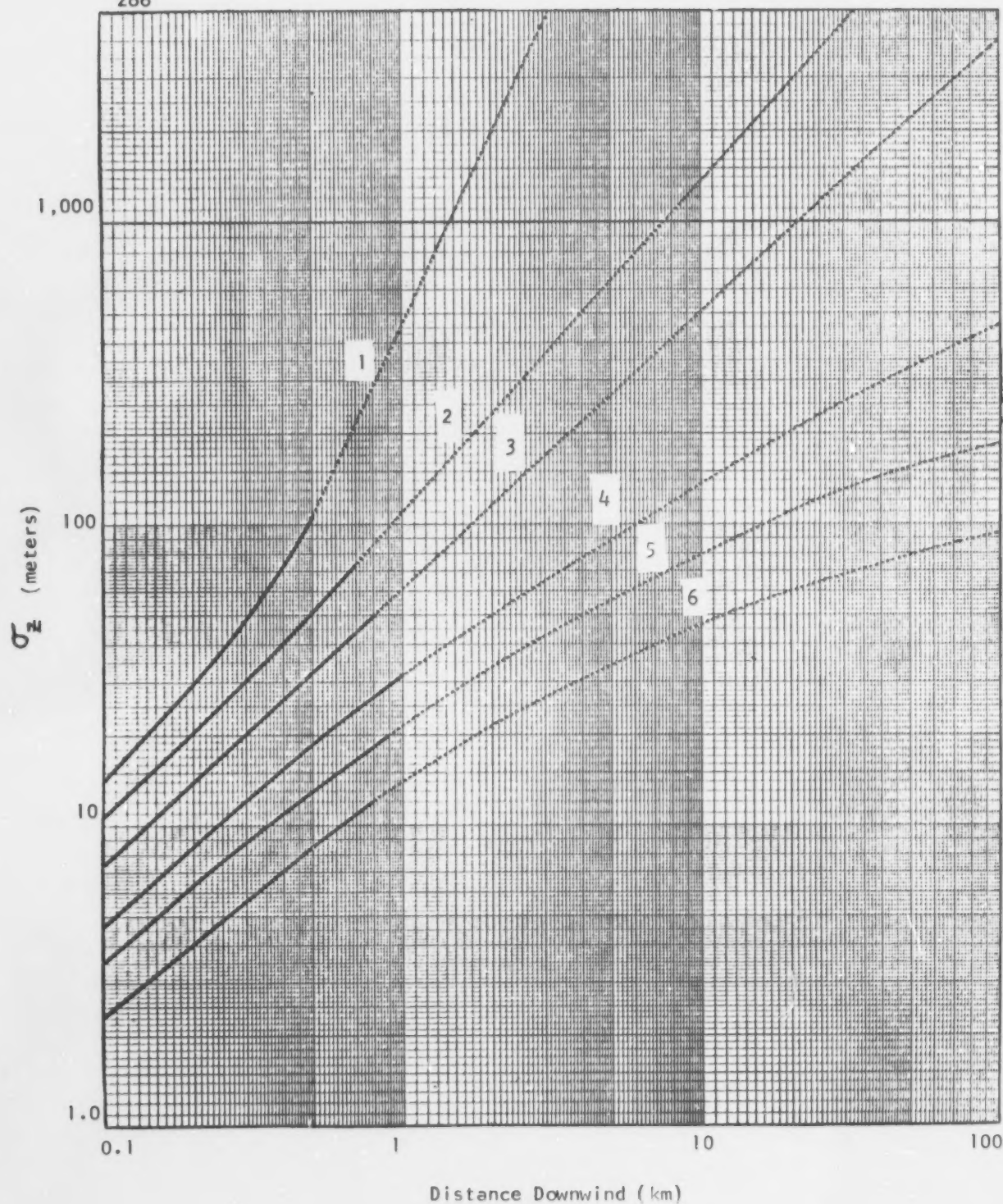


FIGURE 13 - VERTICAL DISPERSION COEFFICIENT AS A FUNCTION OF DOWNWIND DISTANCE FROM THE SOURCE

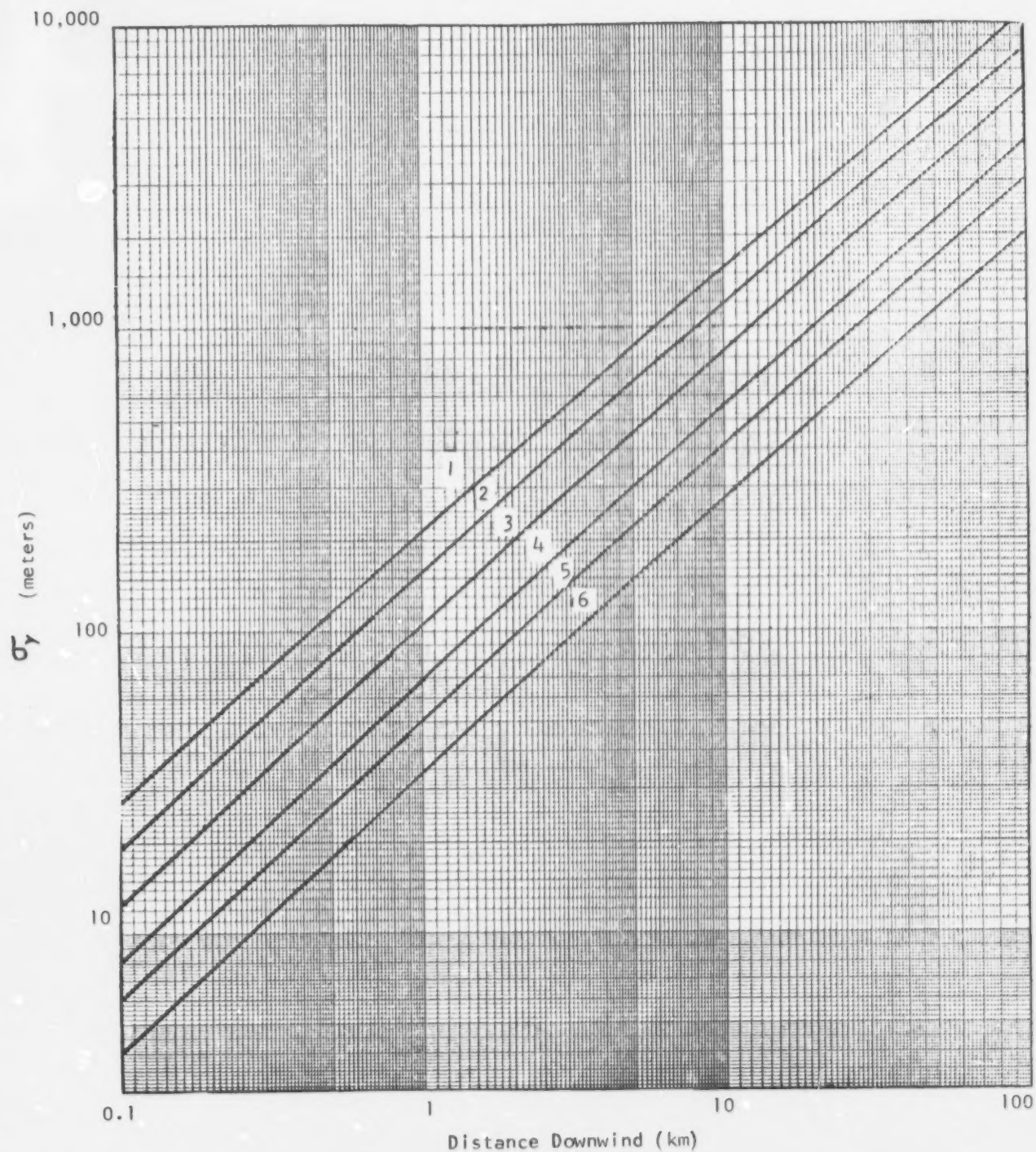


FIGURE 14 - HORIZONTAL DISPERSION COEFFICIENT AS A FUNCTION OF DOWNWIND DISTANCE FROM THE SOURCE

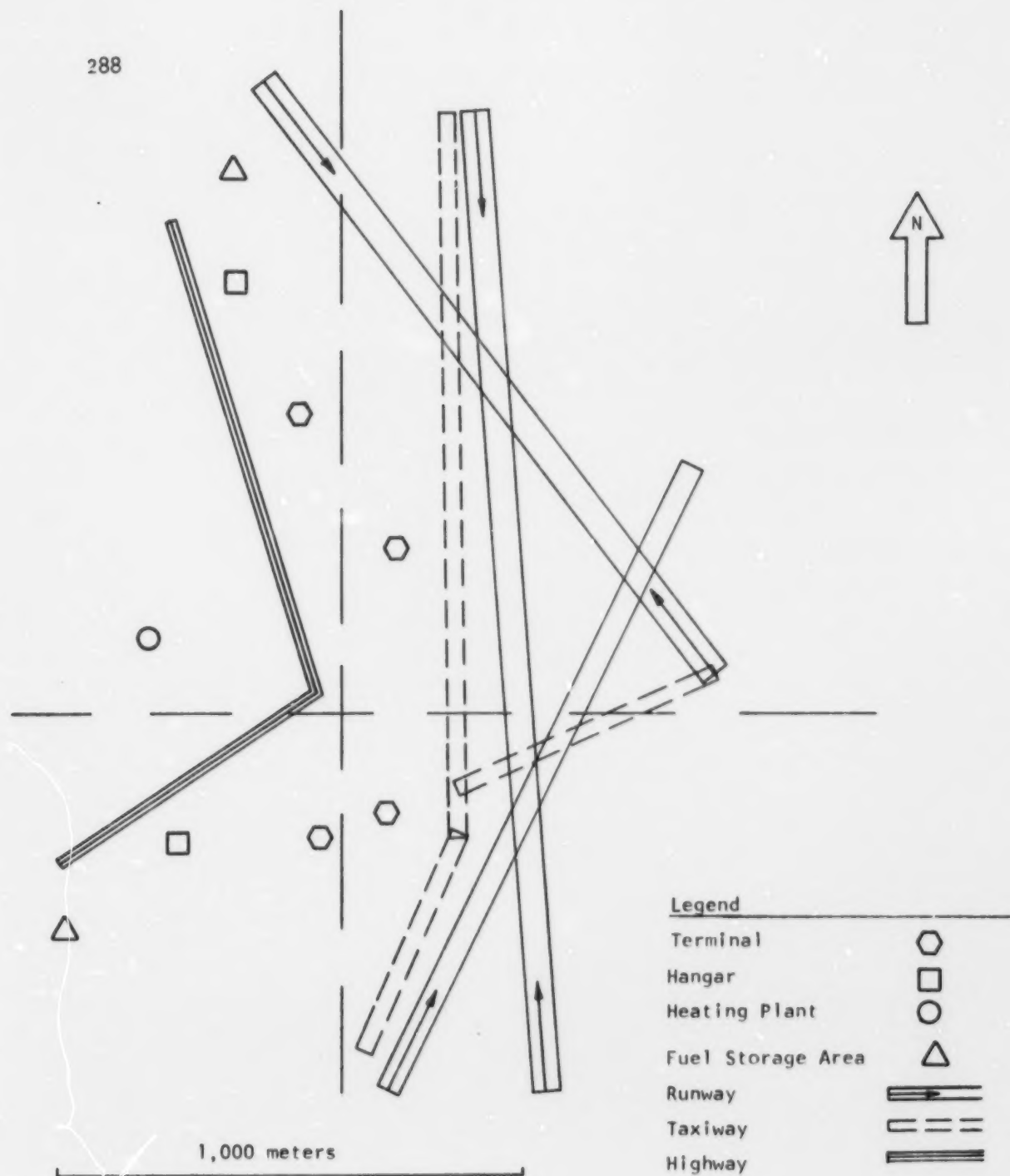


FIGURE 15 - MODEL OF WASHINGTON NATIONAL AIRPORT

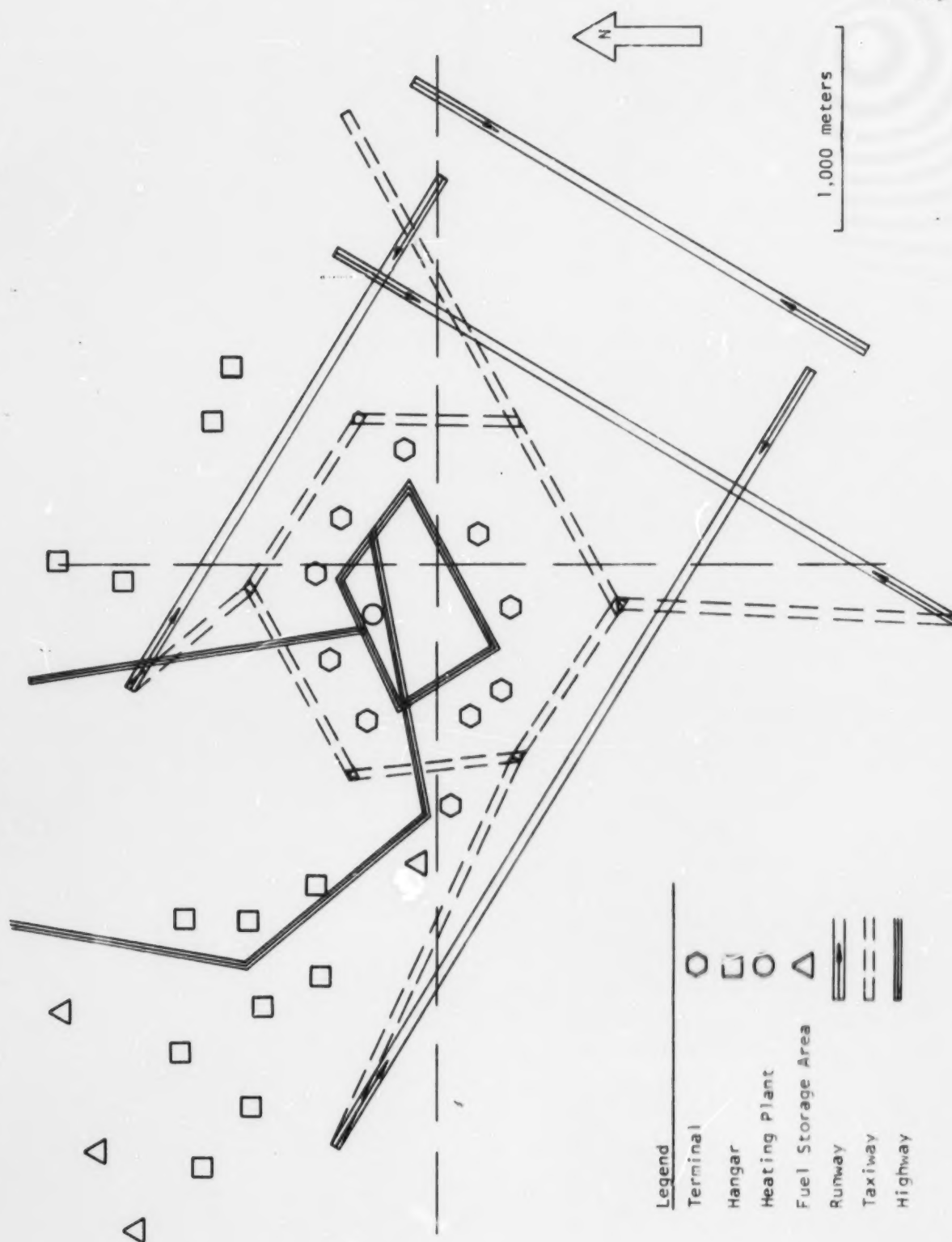


FIGURE 16 - MODEL OF J. F. KENNEDY INTERNATIONAL AIRPORT

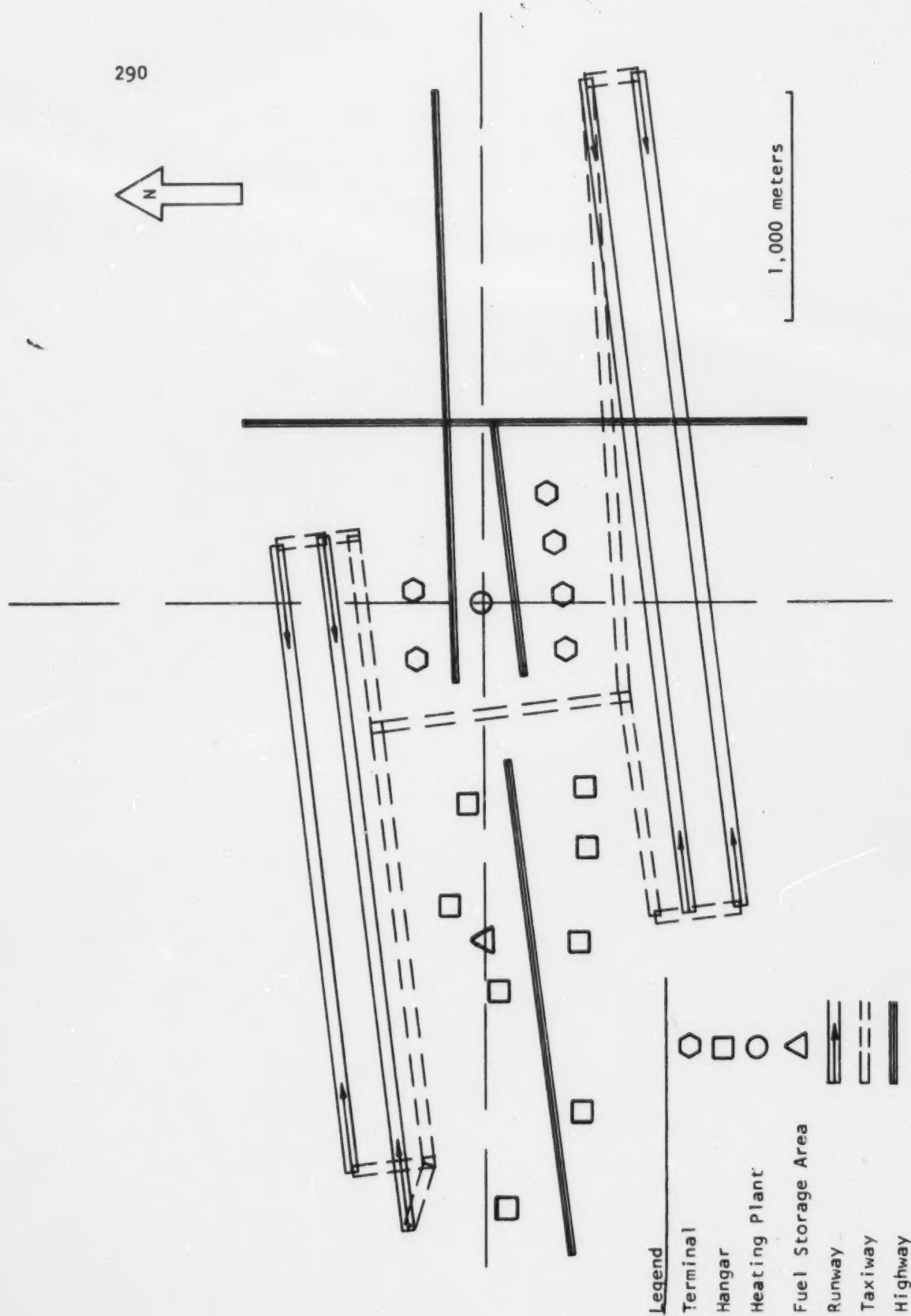


FIGURE 17 - MODEL OF LOS ANGELES INTERNATIONAL AIRPORT

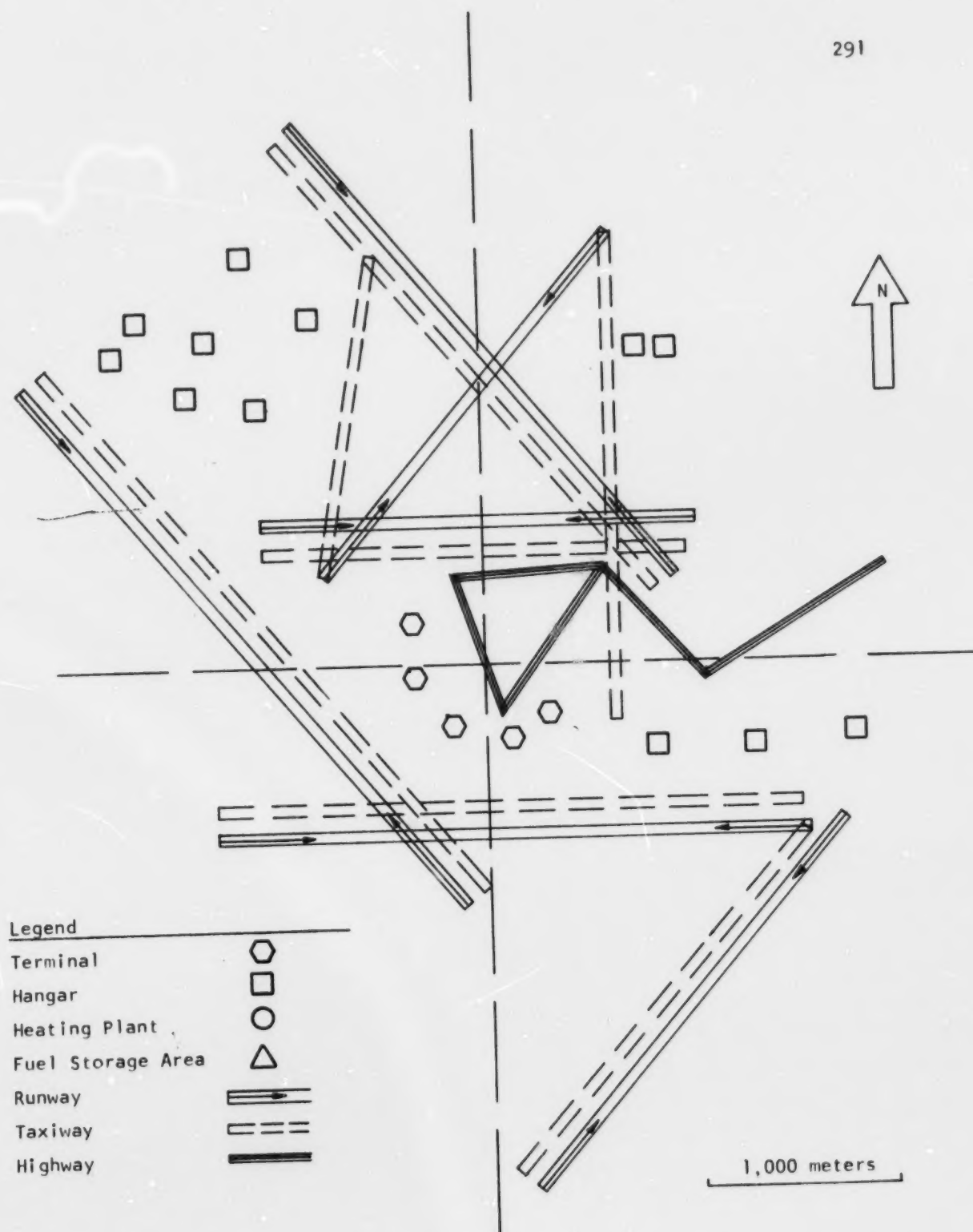


FIGURE 18 - MODEL OF CHICAGO-O'HARE INTERNATIONAL AIRPORT

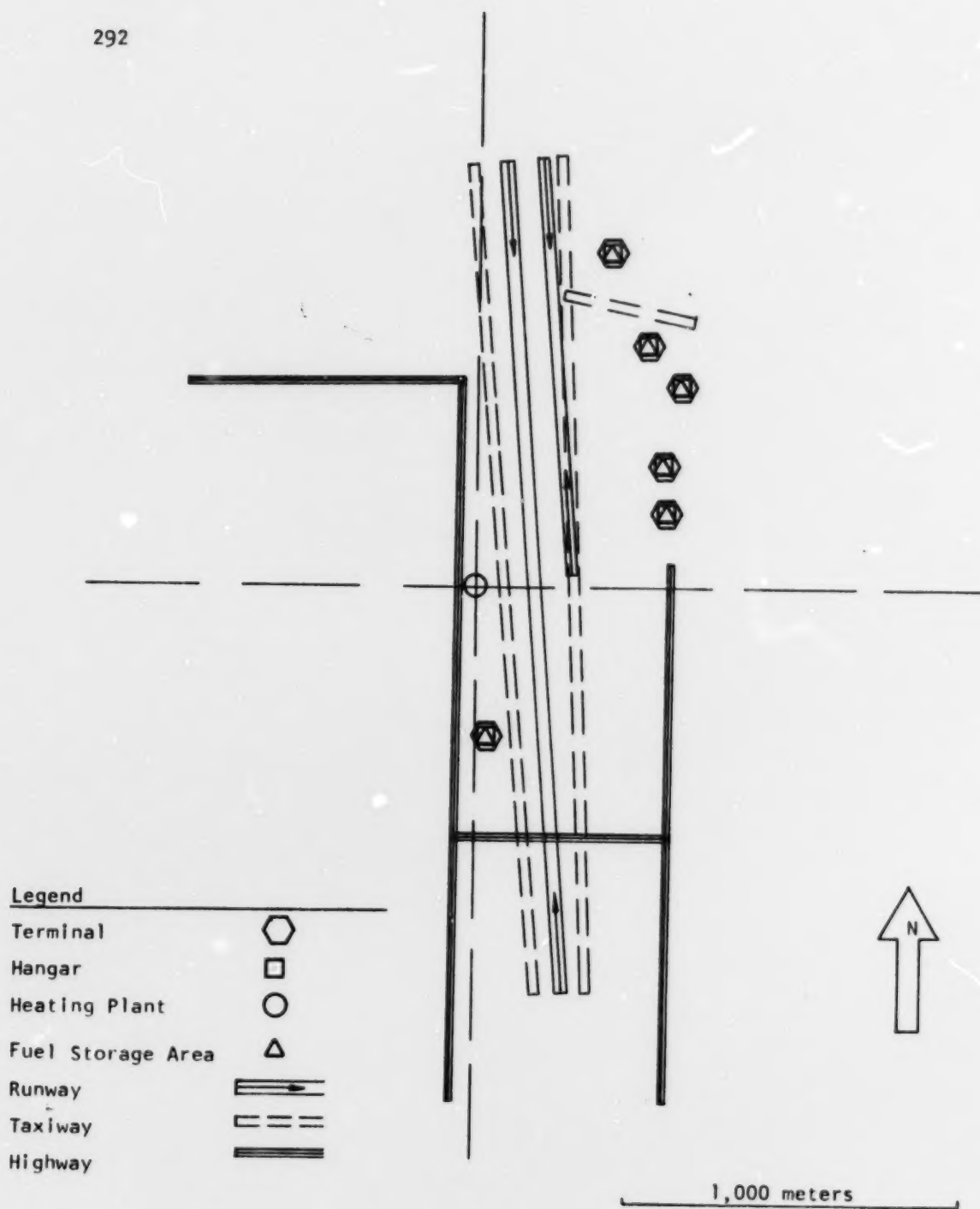


FIGURE 19 - MODEL OF VAN NUYS AIRPORT

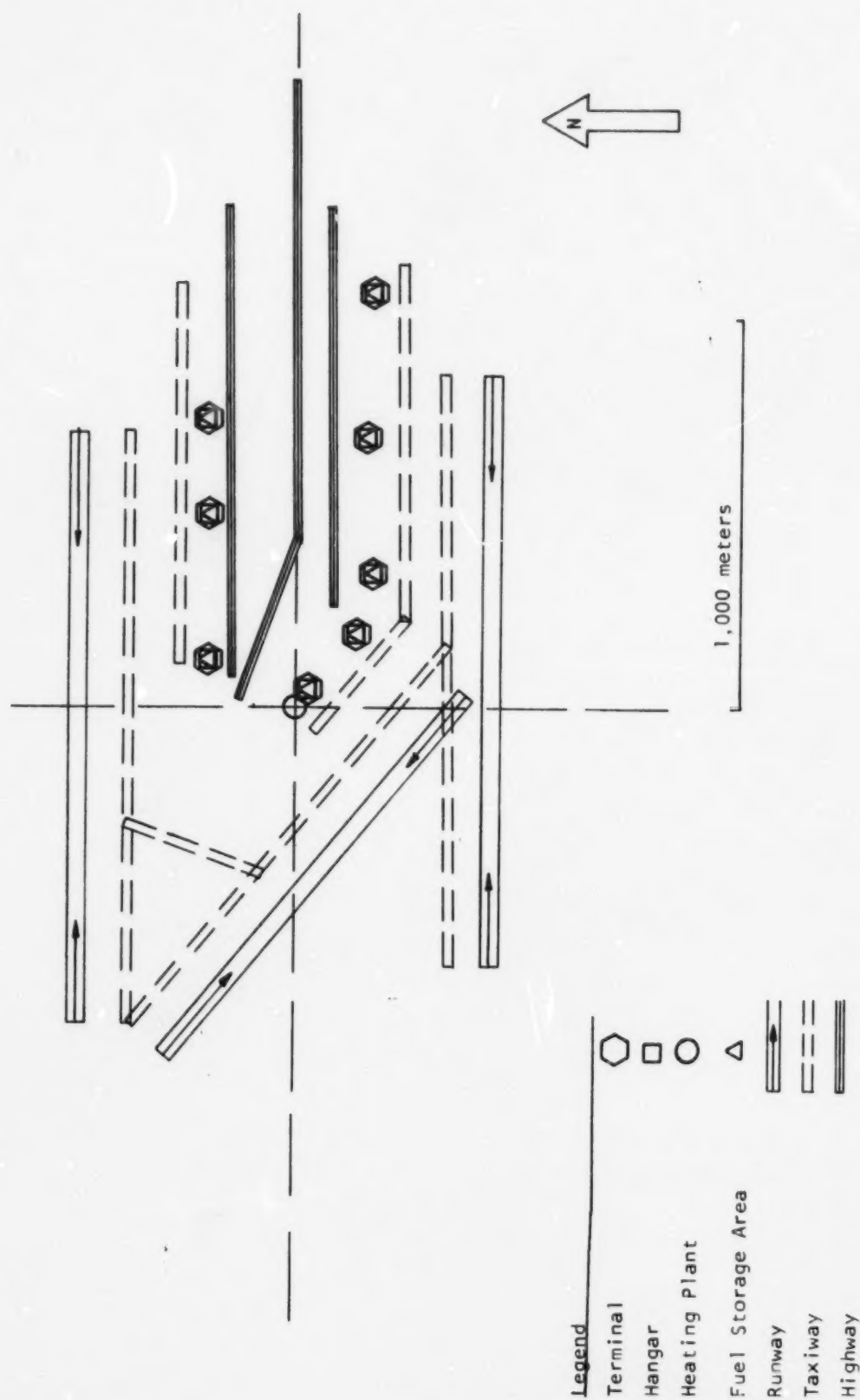


FIGURE 20 - MODEL OF NEW TAMiami AIRPORT

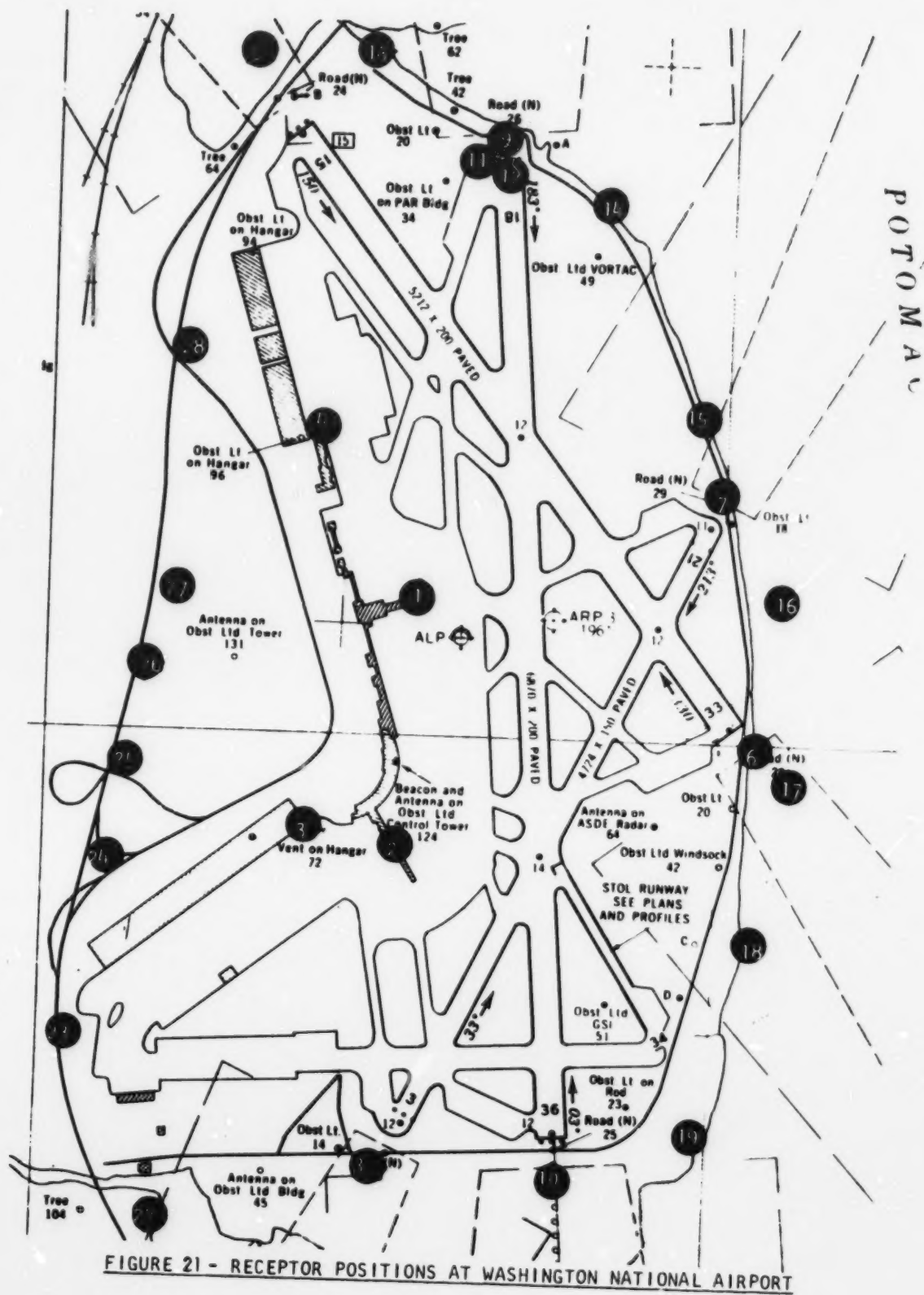




FIGURE 22 - RECEPTOR POSITIONS IN THE VICINITY OF WASHINGTON NATIONAL AIRPORT



FIGURE 23 - RECEPTOR POSITIONS AT J. F. KENNEDY INTERNATIONAL AIRPORT

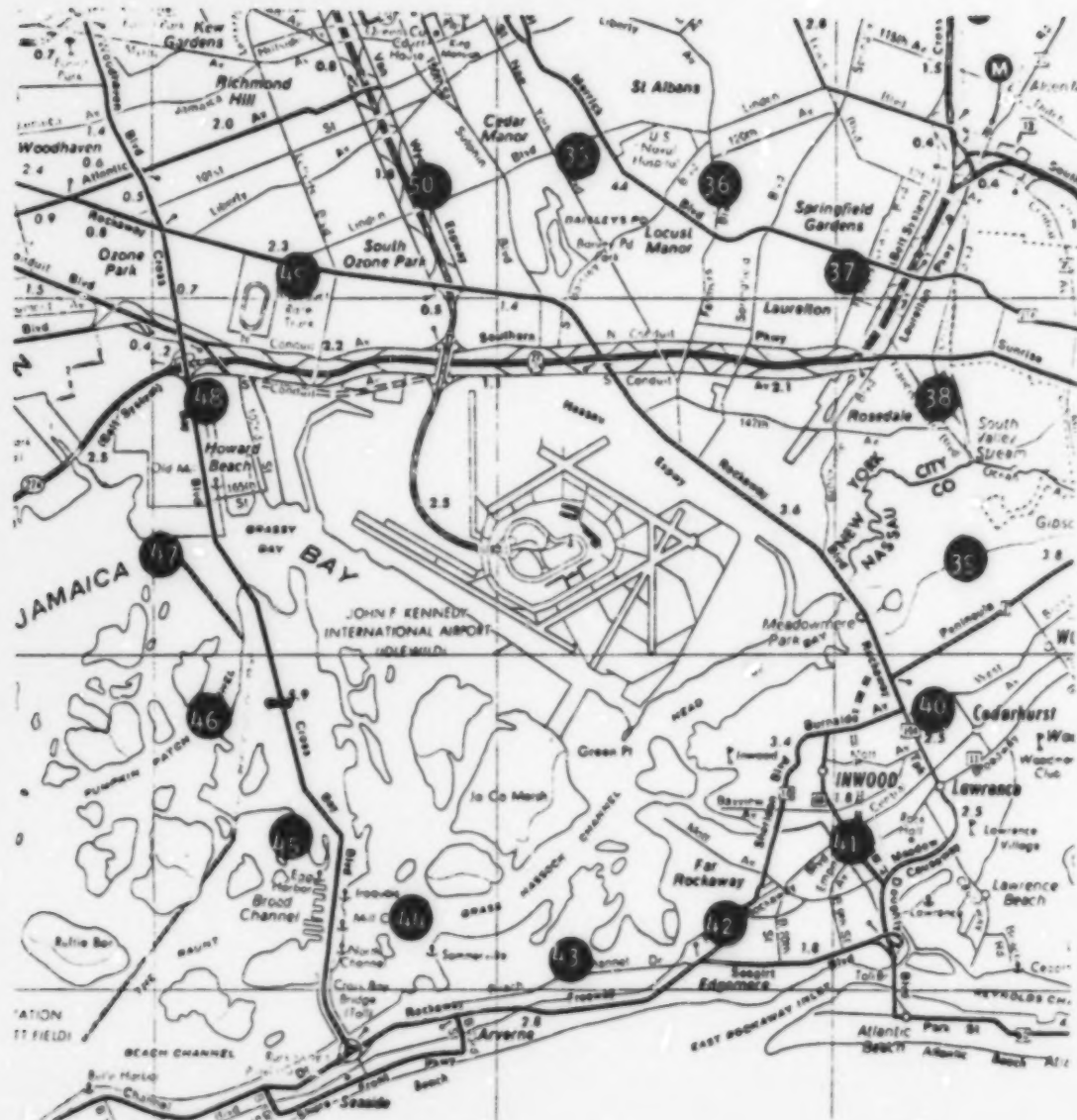


FIGURE 24 - RECEPTOR POSITIONS IN THE VICINITY
OF J. F. KENNEDY INTERNATIONAL AIRPORT

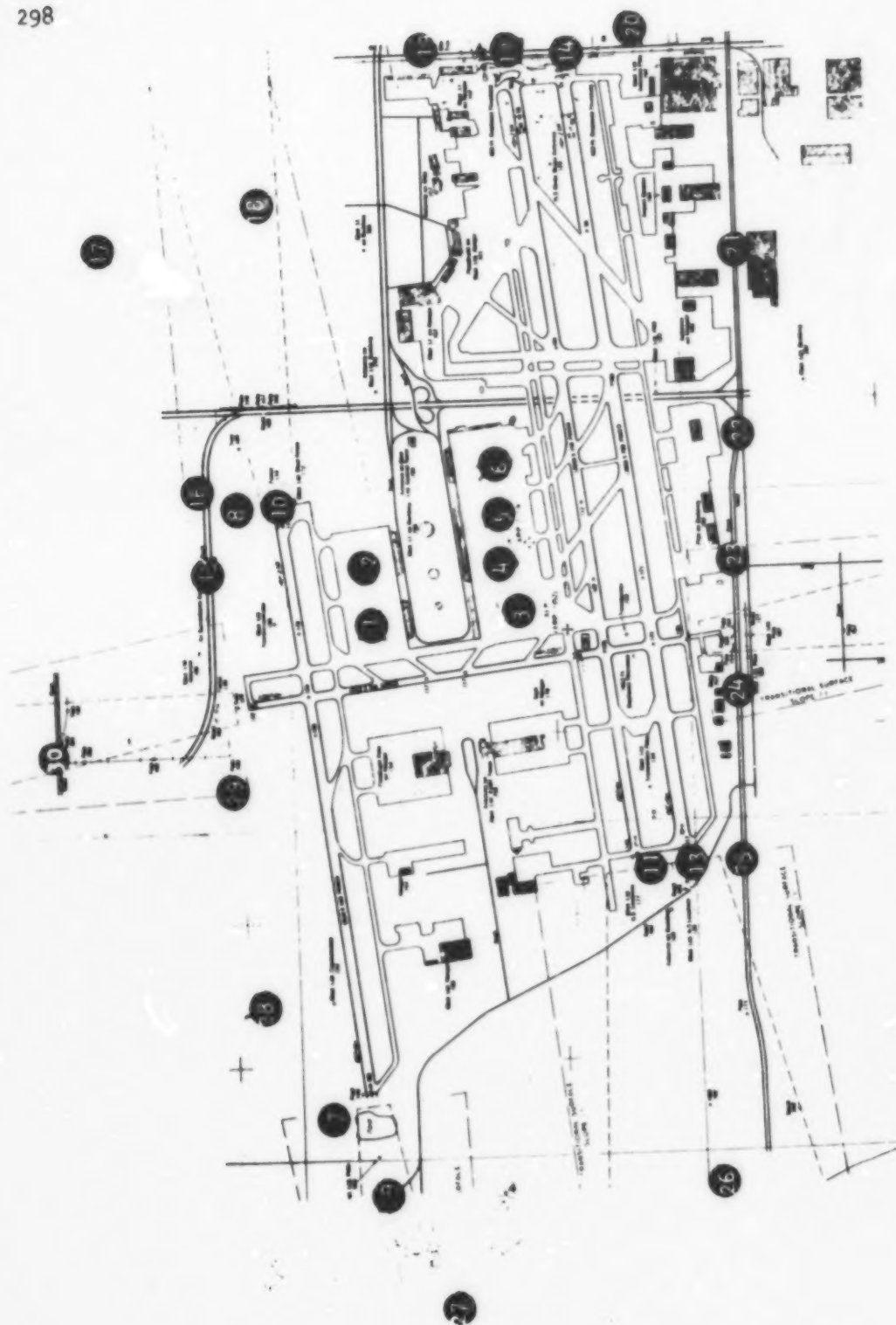


FIGURE 25- RECEPTOR POSITIONS AT LOS ANGELES INTERNATIONAL AIRPORT



FIGURE 26 - RECEPTOR POSITIONS IN THE VICINITY OF LOS ANGELES INTERNATIONAL AIRPORT

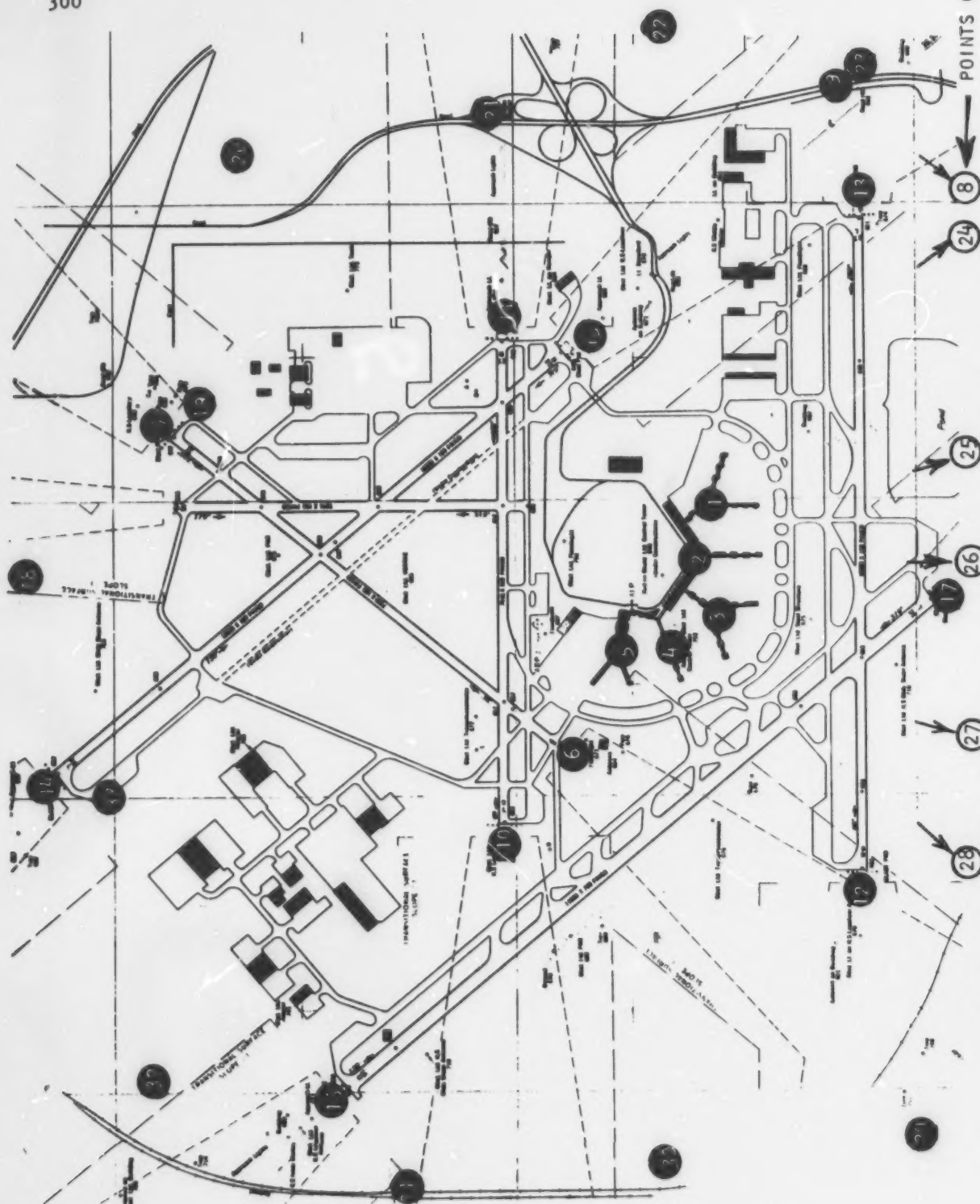


FIGURE 27 - RECEPTOR POSITIONS AT CHICAGO-O'HARE INTERNATIONAL AIRPORT

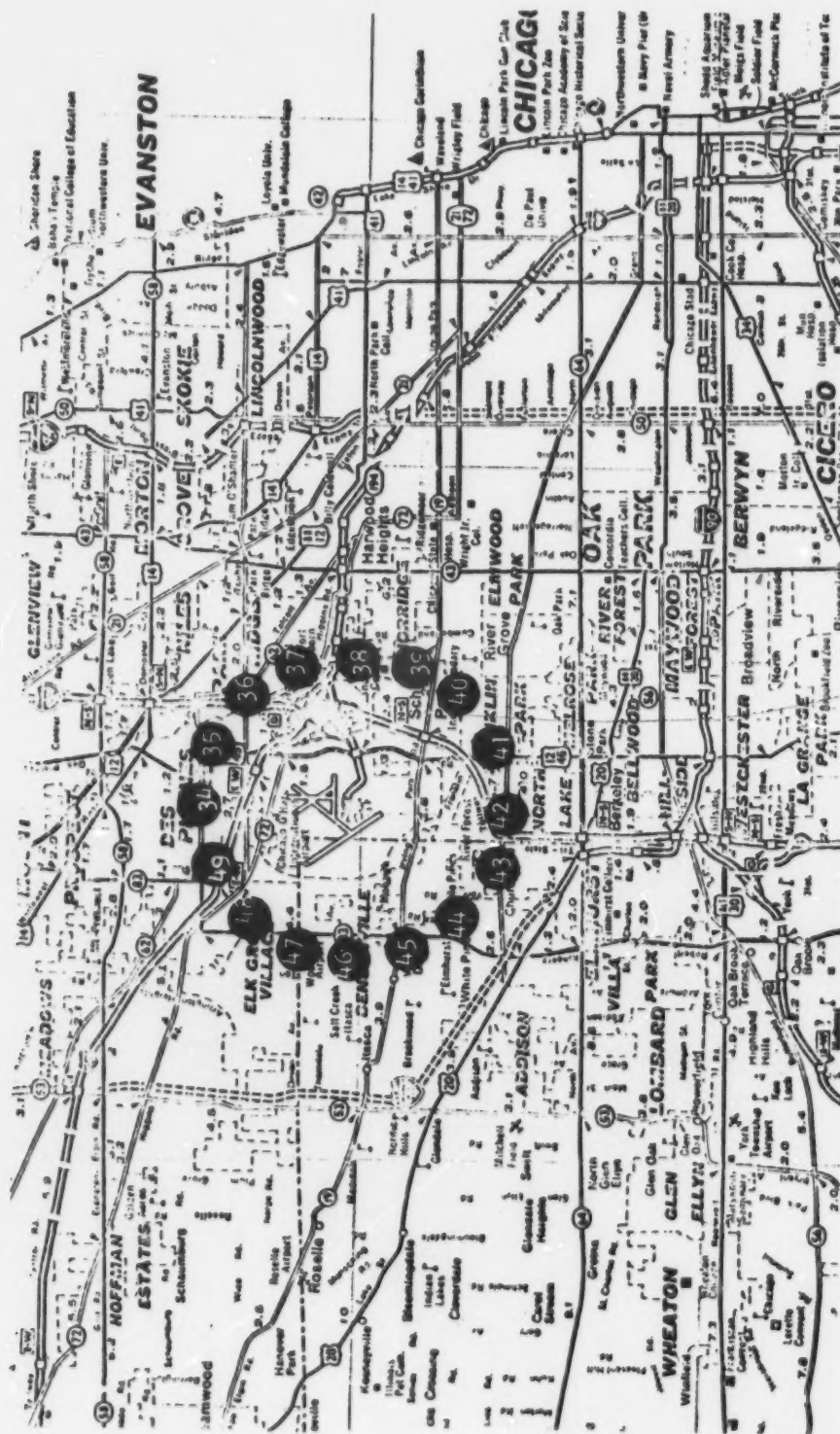


FIGURE 28 - RECEPTOR POSITIONS IN THE VICINITY OF CHICAGO-O'HARE INTERNATIONAL AIRPORT

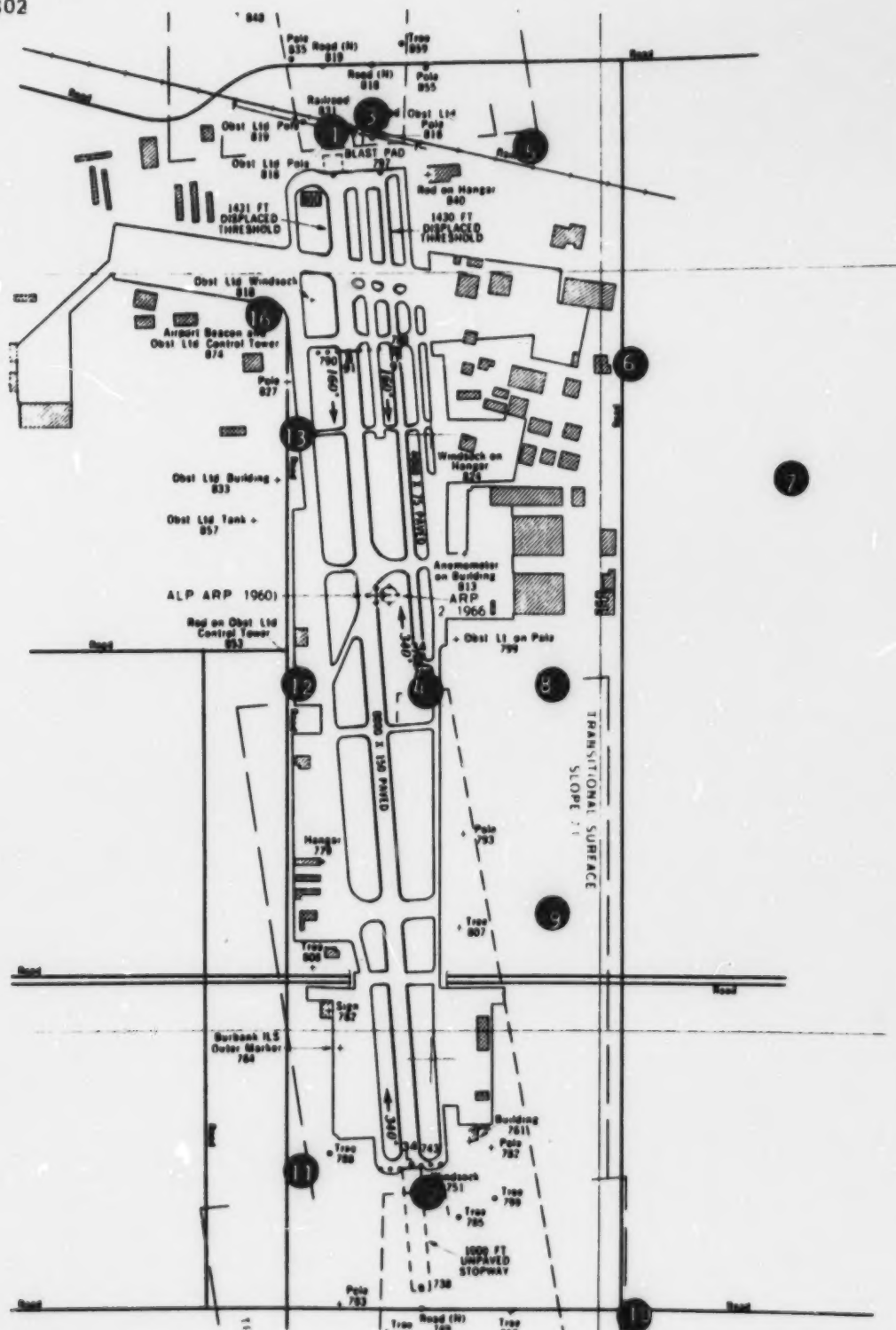


FIGURE 29 - RECEPTOR POSITIONS AT VAN NUYS AIRPORT



FIGURE 30 - RECEPTOR POSITIONS IN THE VICINITY OF VAN NUYS AIRPORT

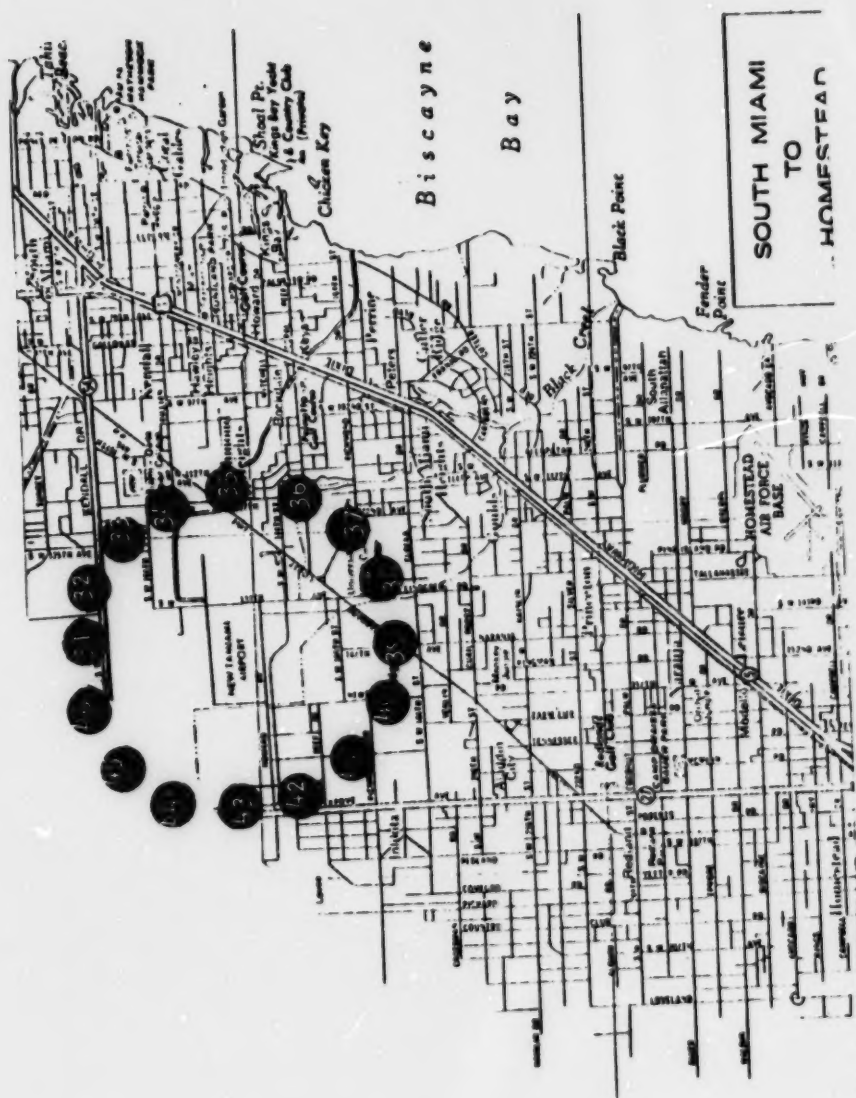
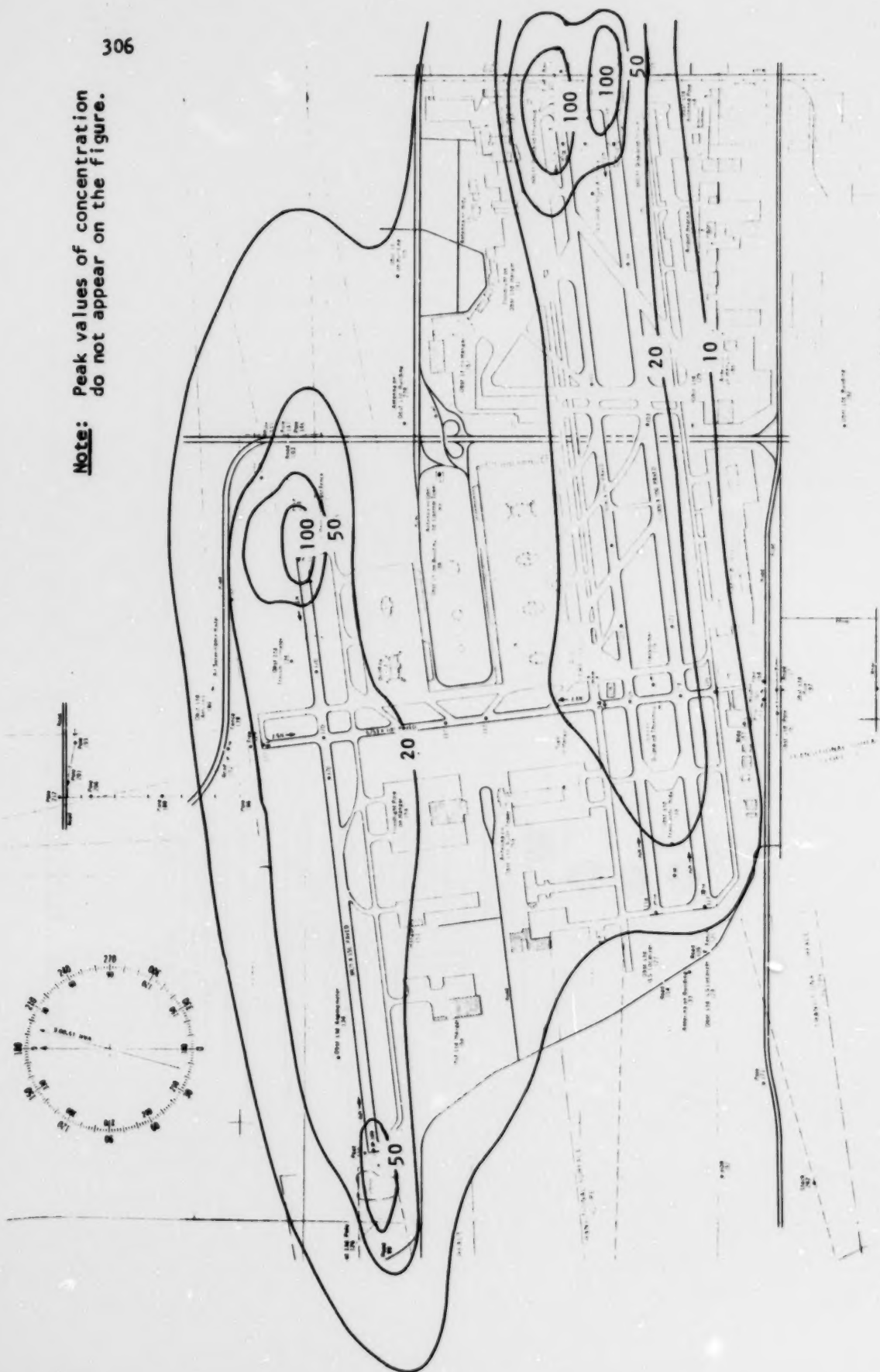


FIGURE 32 - RECEPTOR POSITIONS IN THE VICINITY OF TAMIAHI AIRPORT

Note: Peak values of concentration do not appear on the figure.



(numbers in $\mu\text{g}/\text{m}^3$)

FIGURE 33 - NO_2 ISOPLETHS AT LOS ANGELES INTERNATIONAL: AIRCRAFT SOURCES

Note: Peak values of concentration do not appear on the figure.

(numbers in $\mu\text{g}/\text{m}^3$)

FIGURE 34 - NO₂ ISOPLETHS AT LOS ANGELES INTERNATIONAL: TOTAL EMISSION SOURCES

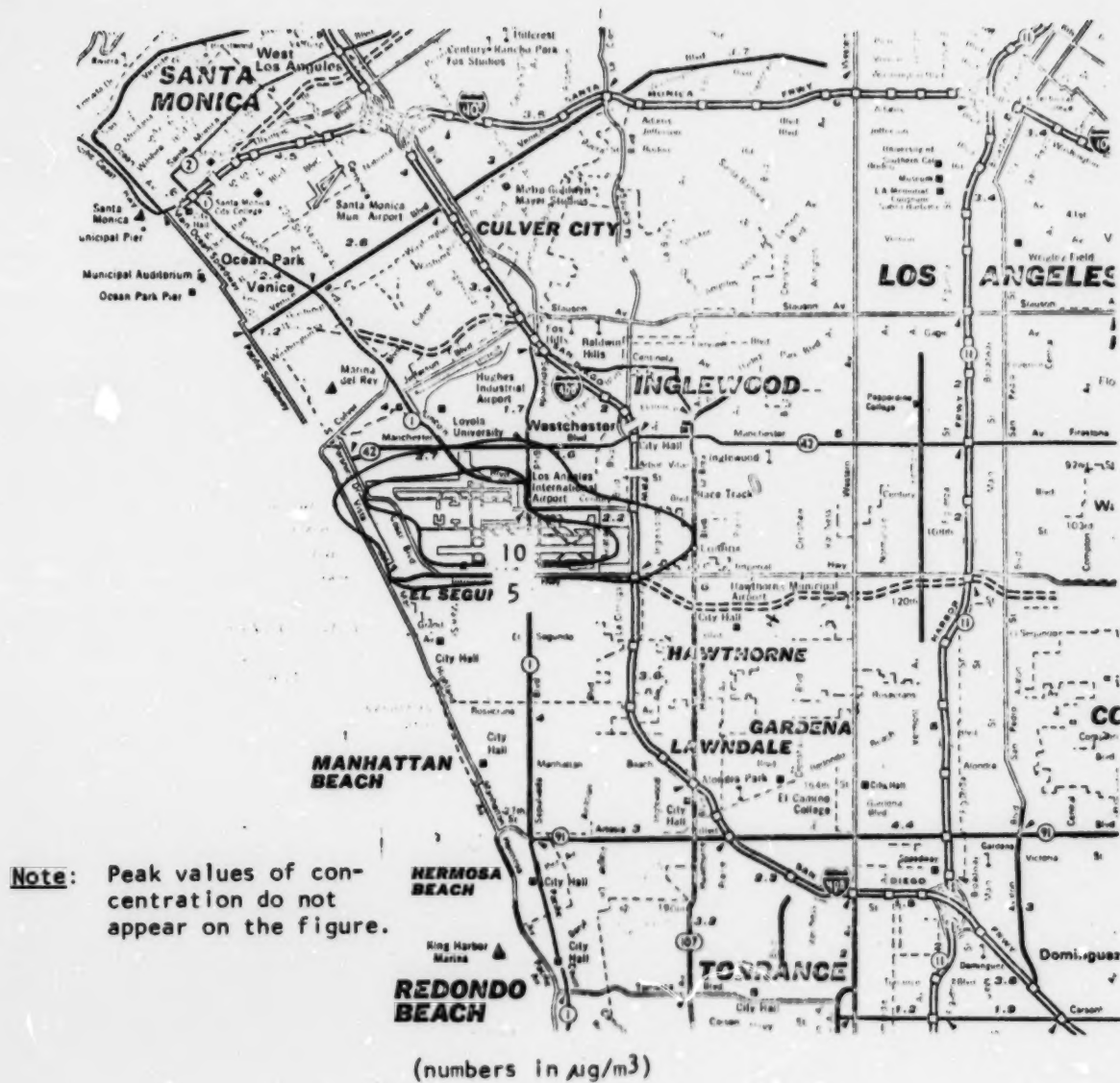


**FIGURE 35 - NO₂ ISOPLETHS IN THE VICINITY OF
LOS ANGELES INTERNATIONAL: AIRCRAFT SOURCES**

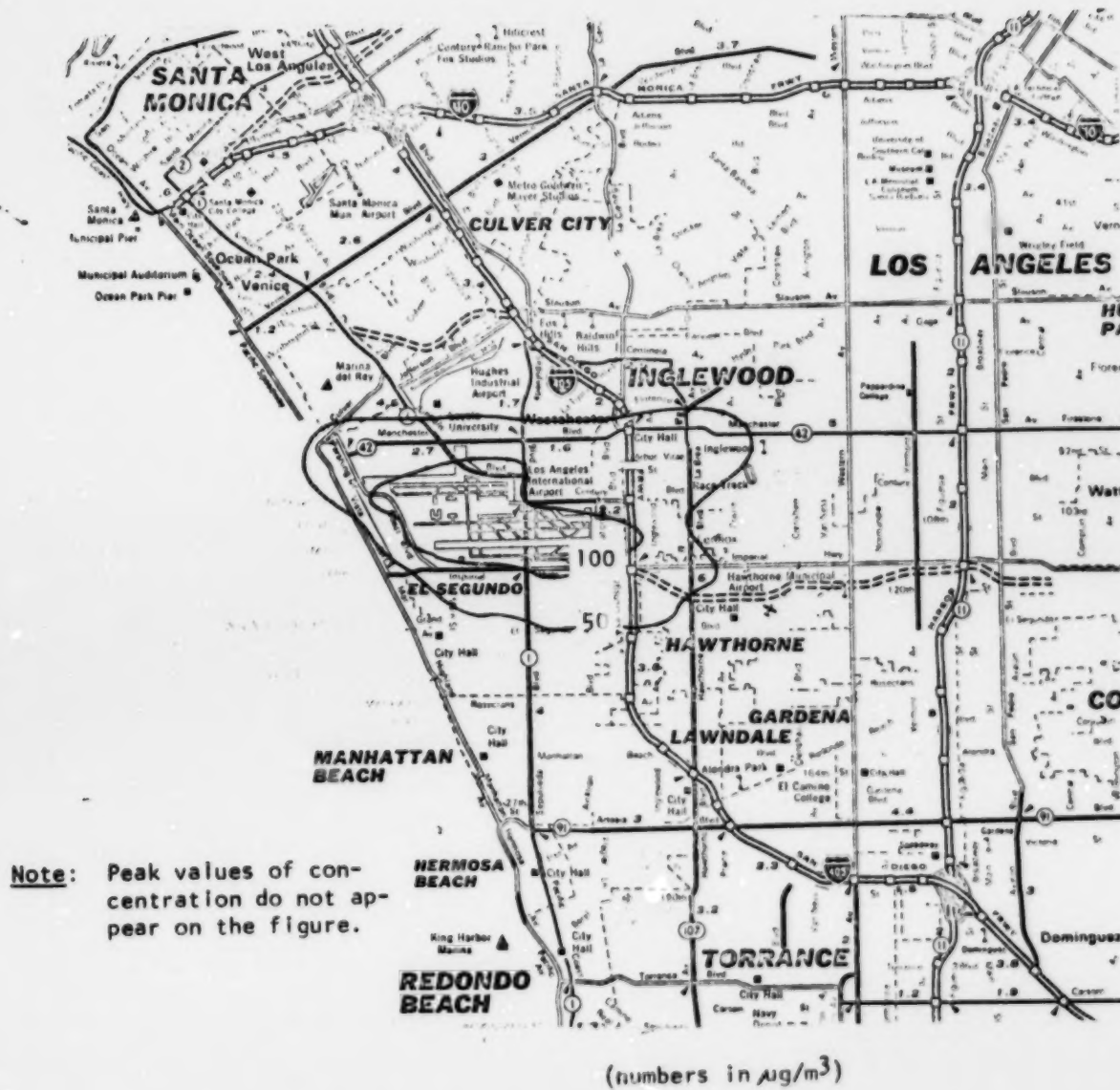


FIGURE 36 - NO₂ ISOPLETHS IN THE VICINITY OF LOS ANGELES INTERNATIONAL: TOTAL EMISSION SOURCES

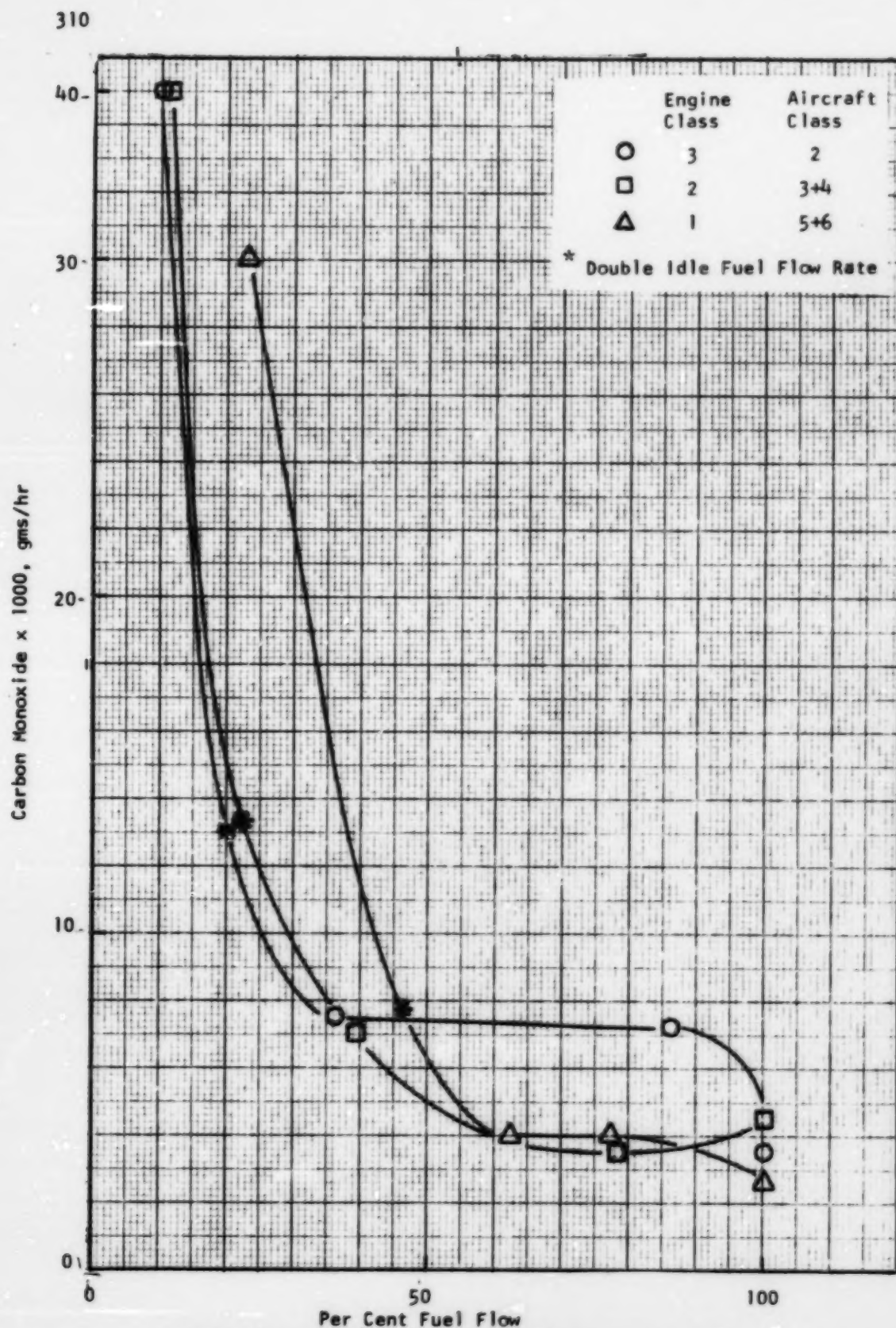


FIGURE 37 - VARIATION OF CARBON MONOXIDE EMISSIONS
WITH FUEL FLOW RATE

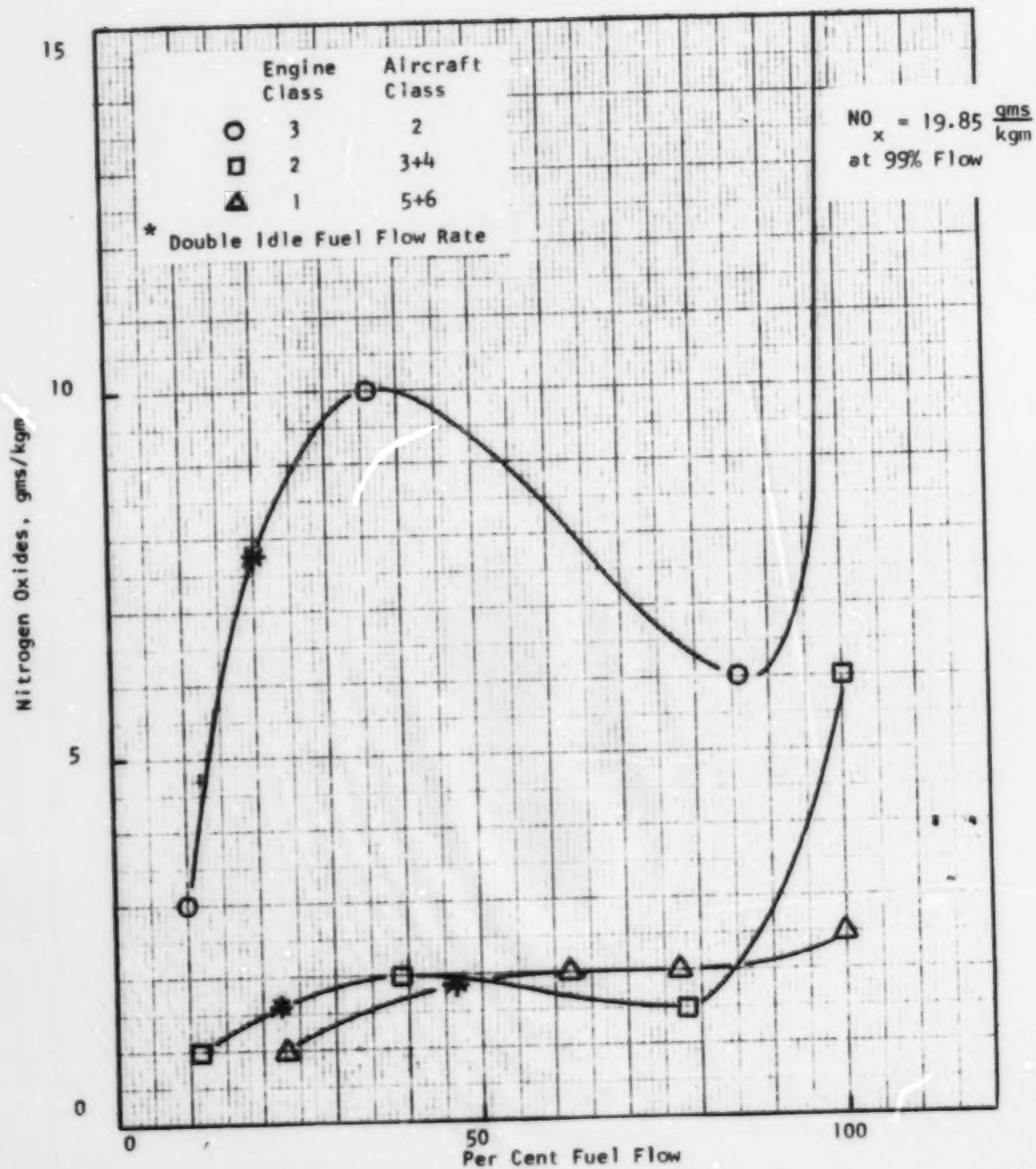


**FIGURE 38 - VARIATION OF NITROGEN OXIDE EMISSIONS
WITH FUEL FLOW RATE**

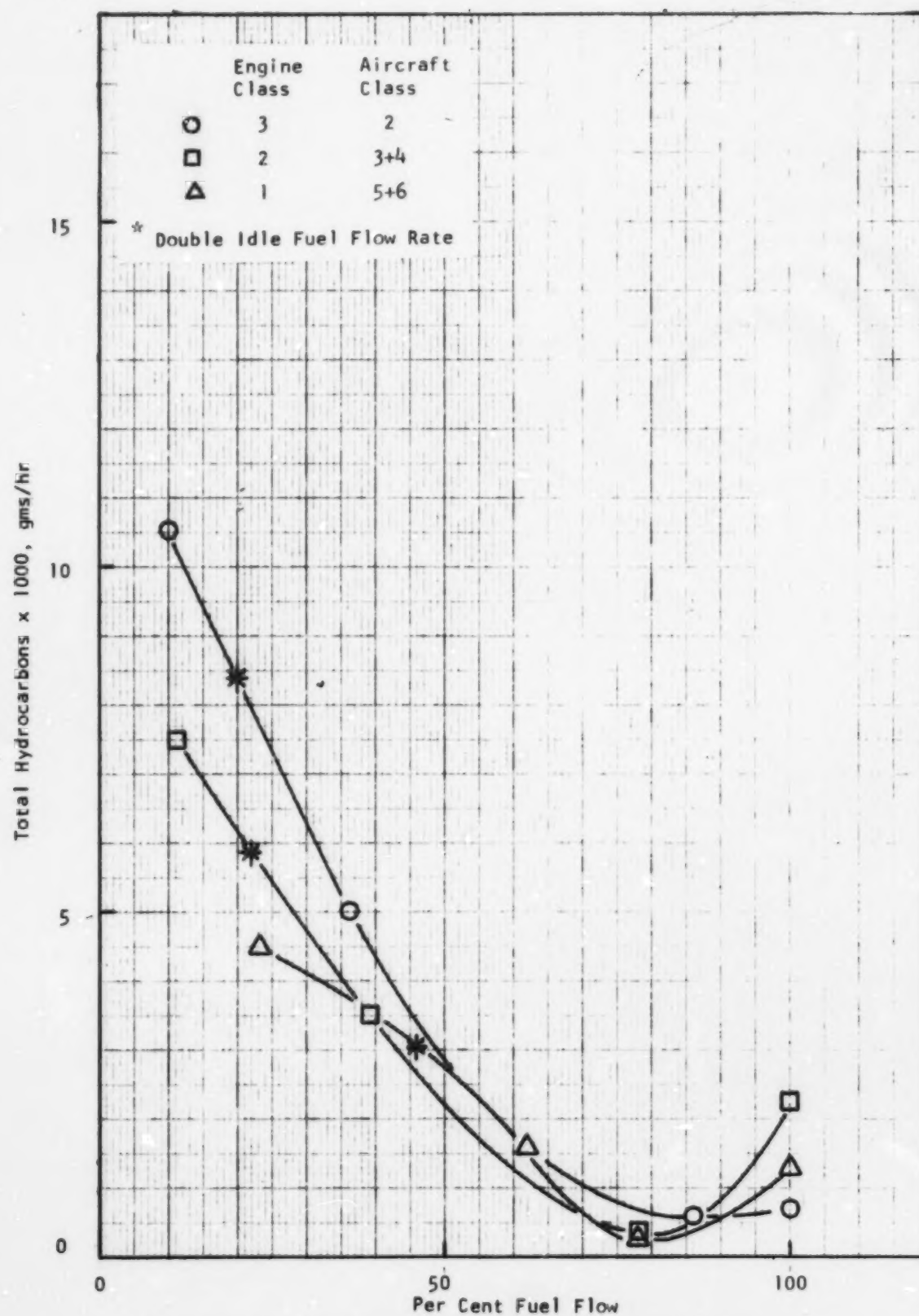


FIGURE 39 - VARIATION OF TOTAL HYDROCARBON EMISSIONS
WITH FUEL FLOW RATE

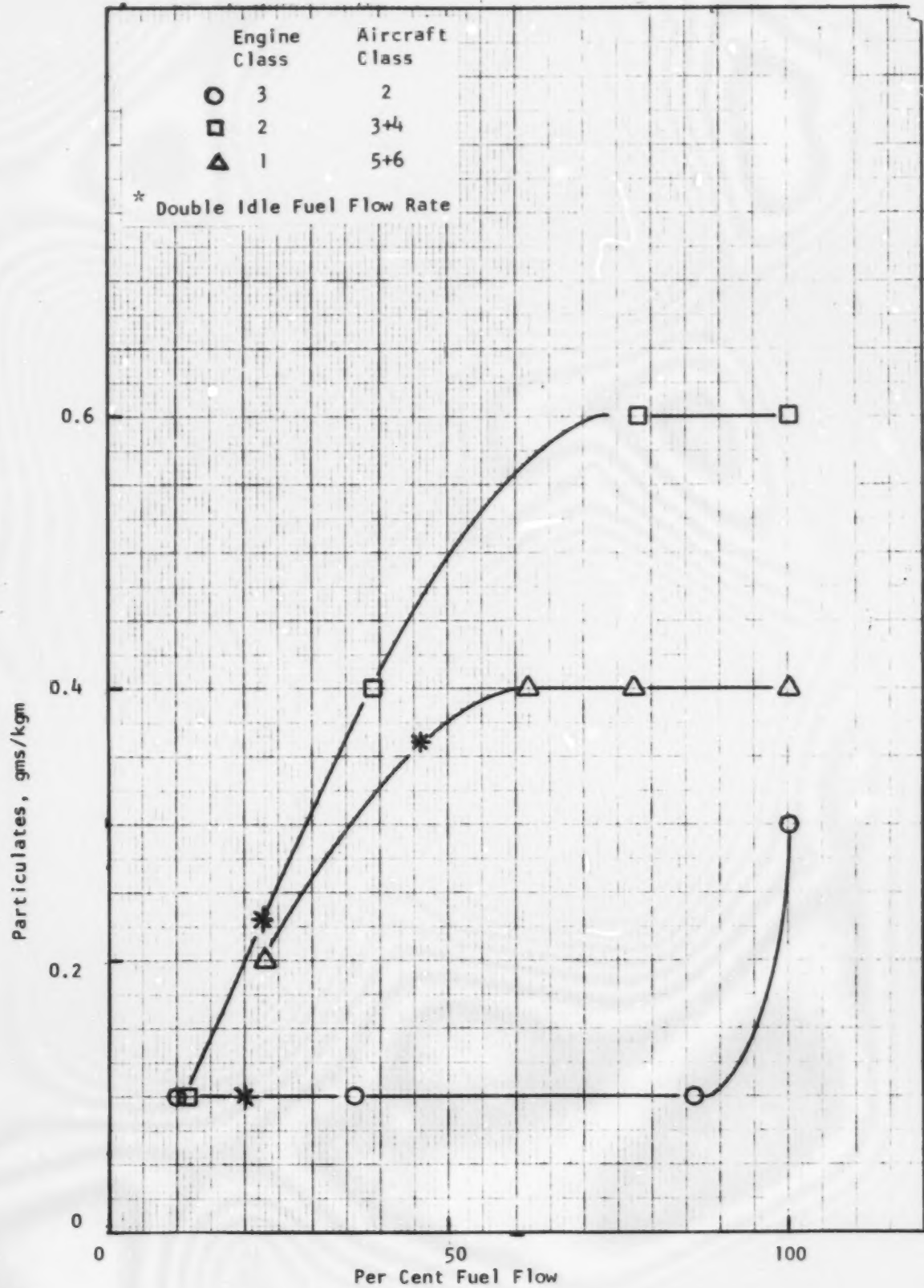


FIGURE 4Q - VARIATION OF PARTICULATE EMISSIONS
WITH FUEL FLOW RATE



APPENDIX IADDITIONAL DATA OBTAINED BY NREC

After completion of its original technical effort on this program, NREC was called upon a number of times by the Environmental Protection Agency to obtain additional data. Although the additional data was related to the investigation described in this report, time did not permit their inclusion in the main body of the report. Rather, the data was furnished directly to EPA for their information and consideration in the preparation of the EPA report, AIRCRAFT EMISSIONS: IMPACT ON AIR QUALITY AND FEASIBILITY OF CONTROL.

The additional data which were obtained by NREC consisted of:

1. Predicted concentrations of carbon monoxide, total hydrocarbons, and particulates for specified time periods from July 20, 1971 through July 23, 1971 at Washington National Airport.
2. Predicted annual average concentrations of nitrogen dioxide at a small number of additional receptor locations at Chicago-O'Hare International Airport and Los Angeles International Airport.
3. Frequency of occurrence of meteorological conditions used to predict short-term maxima concentrations at each of the selected air-carrier airports.
4. Predicted concentrations of carbon monoxide for short-term time periods from May, 1970 through November, 1970 at Los Angeles International Airport.

The first and last of these items were requested by EPA as part of an impromptu investigation of the accuracy of the predicted concentrations in this study. The second and third items were requested to more clearly ascertain whether predicted concentrations exceeded the national primary and secondary ambient air quality standards.

The predicted concentrations at DCA were requested by EPA for comparison with air quality measurements reported in Reference 53. Two sets of computed results were obtained by NREC in accordance with the measurement program. The first set of computed results (Ref 54) consisted

of carbon monoxide and total hydrocarbon concentrations for the time period from 7:30 am to 8:30 am on July 20 through 23, 1971. Receptor locations corresponded to the following measurement sites (see Figure 8):

1. In front of the terminal building at the main entrance to the airport.
2. On the roof of a passenger waiting room.
3. For the first three days, three locations between the south end of runway 18-36 and the south end of runway 3-21.
4. For the last day, four locations adjacent to the north end of runway 18-36.

The second set of computed results (Ref 55) consisted of particulate concentrations for:

1. The time periods 7 am to 11 am, 11 am to 3 pm, 3 pm to 7 pm, and 7 pm to 7 am on the first three days.
2. The time periods 7 am to 11 am and 7 am to 12 am on the last day.

The results for the four time periods on each of the first three days were also combined to provide predicted particulate concentrations for 24-hour averaging periods. Receptor locations corresponded to:

1. In front of the terminal building at the main entrance to the airport.
2. On the roof of a passenger waiting room.
3. Two locations between the south end of runway 18-36 and the south end of runway 3-21.
4. One location adjacent to the north end of runway 18-36.
5. One location at the ASDE radar site near the intersection of runways 18-36 and 3-21.

The aircraft ground traffic information and the meteorological information given in Reference 53 were used to compute both the carbon monoxide and total hydrocarbon concentrations, as well as the particulate concentrations.

Annual average concentrations of nitrogen dioxide were predicted for three additional receptors at LAX and two additional receptors at ORD. The additional receptors at LAX are given relative to receptors shown in Figure 25:

1. Point A1 - 1 km east of point 12.
2. Point A2 - 1 km east of point 14.

3. Point A3 - 1.2 km west of point 28.

The additional receptors at ORD are given relative to receptors shown in Figure 27:

1. Point A1 - 0.4 km north-east of point 19.
2. Point A2 - 0.2 km east of point 9.

The computed concentrations are tabulated below:

Receptor Point	NO ₂ Concentration, $\mu\text{g}/\text{m}^3$	
	Aircraft	Total
LAX - A1	11	62
A2	9.2	65
A3	6.1	48
ORD - A1	17	130
A2	19	140

The short-term national primary and secondary ambient air quality standards specify that the concentrations should not be exceeded more than once per year. Therefore, EPA requested the frequency of yearly occurrence of the meteorological conditions used to obtain the excessive concentrations of carbon monoxide and total hydrocarbons. The frequencies are tabulated below for the selected air-carrier airports:

Airport	Frequency of Occurrence	
	Carbon Monoxide (1-hour period)	Total Hydrocarbons (6 am to 9 am)
DCA	67	6
JFK	10	2
LAX	81	52
ORD*	29	6

Predicted concentrations at LAX were requested by EPA for comparison with air quality measurements taken during the program reported in Reference 37. The results computed by NREC (Ref 56) consisted of carbon monoxide concentrations for the following time periods:

- 6 am to 9 am on September 4, 1970
- 6 am to 9 am on September 9, 1970
- 9 pm to 10 pm on September 16, 1970

* The ORD frequencies are based on five months: January, February, March, October, and December, 1970.

9 pm to 10 pm on October 29, 1970
9 am to 5 pm on September 18, 1970
9 am to 5 pm on September 30, 1970
6 am to 9 am on June 7, 1970
6 am to 9 am on June 8, 1970
3 pm to 6 pm on August 14, 1970
8 am to 11 am on September 3, 1970

The time periods were chosen on the basis of:

1. Fairly close correspondence with the short-term maxima time periods of Table 65.
2. Meteorological conditions are conducive to relatively large concentrations, or relatively large concentrations were measured.
3. For the last four time periods, the wind direction was conducive to a relatively large aircraft contribution at the mobile measurement site (see below).

Receptor locations for each time period corresponded to the permanent measurement sites designated as stations 76, 201, 203, 204, 205, 208, and 209 in Reference 37. In addition, the last four time periods had a receptor location which corresponded to a mobile measurement site. The mobile sites, again using the designations of Reference 37, were:

June 7, 1970 - station 20
June 8, 1970 - station 33
August 14, 1970 - station 20
September 3, 1970 - station 12

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